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Editor's Page

Shifting to EVs

While it may not be obvious to the average driver, the number of electric vehicles (EVs) on the roads is increasing rapidly, and correspondingly, the number of available charging stations is also growing. Worldwide, about two million electric cars were on the road in 2016, and another one million or so were sold in 2017, with China and the U.S. leading as the largest electric car markets, according to the International Energy Agency (IEA; www.iea.org). Forecasts predict astounding growth in the number of EVs by 2030.

Technology driven

One of the main technological enablers to the growth in EVs is the progress that has been made in batteries, both in improved performance and cost reduction. The chemical process industries (CPI) are playing a vital role in this area. For example, just last month, Cabot Corp. (www.cabotcorp.com) was selected by the U.S. Dept. of Energy to be a technology partner for the development of low-cobalt cathodes for lithium-ion batteries as part of an $80-million investment in advanced vehicle technologies research. The booming demand for lithium-ion batteries is driving innovation in mining, processing, battery chemistries and more (see "Lithium Battery Demand Drives Process Evolution," *CE* April 2018). A quick search through the pages of *Chemical Engineering* and on our website reveals a broad spectrum of battery-related activities in the CPI.

Support driven

Another driver for the growth in EVs is policy support from governments around the world in a global effort to improve our environment. In the U.S., a number of state initiatives are paving the way. In September, for example, New York's Governor Cuomo announced that the state will use $127.7 million that was received from the 2016 Volkswagen settlement to "dramatically increase the number of electric vehicles and other 'clean' vehicles in the state." And the New York Power Authority (NYPA; www.nypa.gov) has committed up to $250 million through 2025 to address key infrastructure and market gaps to accelerate the adoption of EVs. NYPA has also issued a Request for Information (RFI) to identify public and private partnerships to help in this effort.

In addition to government support, automobile manufacturers and electricity suppliers are joining forces in support of EVs. Last month, a nonprofit organization called Veloz (www.veloz.org) was formed in California with the aim of accelerating the shift to EVs. Veloz is an alliance among representatives from key car manufacturers, providers of charging stations for EVs, electricity providers and others.

Roadways of the future

In addition to advances in batteries and other vehicle components, work on innovative charging technologies is progressing. Last month, Momentum Dynamics Corp. (www.momentumdynamics.com) announced that it will deliver wireless charging stations for electric transit buses in Massachusetts. The systems can be installed in the roadway to provide on-route charging.

With all of these advances, I expect our roadways and vehicles will look very different in a relatively short time. And innovative engineers are helping to pave the way for these changes. ■

Dorothy Lozowski, Editorial Director

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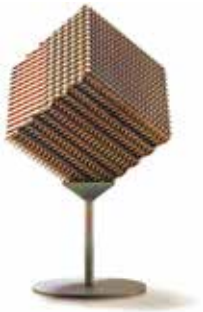

A chemical vapor deposition (CVD) process that bonds a silicon-oxide film to metal surfaces of any shape is being scaled up by Wicoatec GmbH (Ulm, Germany; www.wicoatec.com). Serial production started in 2017 with pilot-scale equipment, and capacities will be tripled by December 2018. As the next step, parent company Wieland Group (Ulm; www.wieland.com), decided to invest another €6 million in next-generation cleaning and coating equipment.

The Wicoatec process is a patented CVD process that operates at atmospheric pressure. Alkosiloxane precursors [tetramethyl orthosilicate (TMOS) or tetraethyl orthosilicate (TEOS)] and some minor additives are vaporized and introduced into the coating chamber, which contains the cleaned substrate to be coated. There, the methoxy groups of TMOS (or ethoxy groups of TEOS) are hydrolyzed into silanols, which are unstable and condense as SiO_2 on the metal surface, explains managing director Till Merkel. The SiO_2 layers form chemical bonds to the metal oxides on the surface — as metal silicates do in nature, says Merkel.

"Atmospheric CVD is nothing new or revolutionary. However, we have found a way to transform the well-known single-pass vacuum-based CVD process into a multi-pass atmospheric process by backmixing of the gas phase. At the same time, process temperatures decreased from 900°C to 300°C," says Merkel.

Because WiCoat organo-ceramic coatings are chemically bonded to the metal, they provide improved corrosion and fouling resistance by modifying physico-chemical surface properties. Also, Wicoat layers are ultrathin (0.05–5 μm), so the dimensions of the component are essentially unchanged.

"We can provide a homogeneous coating where other processes fail to provide any coating at all — for example, inside surfaces of plate heat exchangers (photo), distillation columns and 3-D printed parts," says Merkel. "We believe — and ongoing projects with the process industries underline this — that this feature is really exciting to the industry."

Two new catalysts for continuous-flow synthesis

Shu Kobayashi and colleagues at the University of Tokyo (Japan; www.chem.s.u-tokyo.ac.jp) reported on two new catalysts for synthesizing fine chemicals using their continuous-flow reactor system.

The first technology is a novel methodology using $CsF{\cdot}Al_2O_3$ as a highly efficient, environmentally benign, and reusable solid-base catalyst to synthesize glutamic acid derivatives by stereoselective 1,4-addition of glycine derivatives to α,β-unsaturated esters. $CsF{\cdot}Al_2O_3$ (with 40 wt.% CsF and thermal treatment at 200°C under vacuum) showed not only great selectivity toward 1,4-addition reactions (94% after 38 h) by suppressing the undesired formation of pyrrolidine derivations by [3+2] cycloadditions (with 1,4:[3+2] = 99:1), but also offered high yields for the 1,4-adduct with excellent anti diastereoselectivities (with anti:syn better than 99:1). Continuous-flow synthesis (for more than 50 days) of 3-methyl glutamic acid derivative was successfully demonstrated by using this solid-base catalysis. They are expecting that the developed procedure will be applied for the various continuous flow fine synthesis of stereoselective catalytic reactions.

The second technology is the hydrogenation of arenes, an important reaction not only for hydrogen storage and transport but also for the synthesis of functional molecules, such as pharmaceuticals and biologically active compounds. The researchers developed heterogeneous Rh–Pt bimetallic nanoparticle catalysts for the hydrogenation of arenes with inexpensive polysilane as support. The catalysts could be used in both batch and continuous-flow systems with high performance under mild conditions and showed wide substrate generality. In the continuous-flow system, the product could be obtained by simply passing the substrate and 1 atm H_2 through a column packed with the catalyst. Remarkably, much higher catalytic performance was observed in the flow system than in the batch system, and extremely strong durability under continuous-flow conditions was demonstrated after a continuous run of more than 50 days. The turnover number was found to be more than 3.4×10^5.

Edited by:
Gerald Ondrey

O_2 RECYCLING

A beta field trial has been successfully completed for an adsorption-based technology designed to separate unreacted oxygen in ozone-generating systems. The technology, known as Ozora, was developed by Linde LLC (Bridgewater, N.J.; www.lindeus.com), and was originally launched last year (*Chem. Eng.,* Dec. 2017, p. 11). The 9-month beta trial took place at a municipal water system in Haworth, N.J., and achieved 60% oxygen recovery in continuous operation for 1,500 h. Following the field trial, a full-scale Ozora system will be installed at the site. Onsite O_3 generation is used by many municipal water utilities to disinfect drinking water. Corona-dischage ozone generators typically only convert 10% of O_2 molecules to O_3, with the rest lost. Ozora captures unreacted O_2 molecules and recycles them to the O_3 generator.

'GREEN' QUANTUM DOTS

Researchers at the University of Zurich (UZH; Switzerland; www.chem.uzh.ch), in collaboration with scientists from Southwest Petroleum University (Chengdu) and the Chinese Academy of Sciences (Beijing), have developed a new photocatalyst for directly producing H_2 from water and sunlight. The nanoparticles are made by adding zinc sulfide onto the surface of indium-based quantum dots (QDs). These all-inorganic sulfide-capped InP and In/ZnS QDs are as competitive, and far less toxic, than alternative QD catalysts, which contain cadmium, says professor Greta Patzke at UZH's Department of Chemistry, and lead author of the study published last month in *Nature Communications*.

(Continues on p. 8)

QDs are inorganic semiconductor nanoparticles with unique physical properties, such as tunable band gaps, large absorption coefficients and strong emissions, which makes them promising new materials for applications in bioimaging, display technologies and artificial photosynthesis.

The new photocatalyst is made of 3-nm particles with an indium phosphide core and a thin surrounding layer of zinc sulfide and sulfide ligands. Sulfide ligands on the QD surface were found to facilitate the crucial steps involved in light-driven chemical reactions, namely the efficient separation of charge carriers and their rapid transfer to the nanoparticle surface. "Compared to the QDs that contain cadmium, the new composites are not only environmentally friendly, but also highly efficient when it comes to producing hydrogen from light and water," explains Patzke. Turnover numbers of up to 128,000 per QD and an internal quantum yield of 31% (at wavelength of 525 nm) were observed.

NIR ON A SMARTPHONE

Last month, BASF SE (Ludwigshafen, Germany: www.basf.com) introduced Hertzstück, a near infrared (NIR) detector that may soon transform smartphones into portable laboratories. This NIR sensor for wavelengths of 1–3 µm was developed by the startup trinamiX GmbH (Ludwigshafen; www.trinamix.de), a spin-off and wholly owned subsidiary of BASF founded in 2015. The patented thin-film encapsulation of the functional semiconductor layer is very stable and protects the sensor from environmental influences such as water and oxygen. This miniaturization means that Hertzstück can soon be installed as a sensor chip on the circuit board of a smartphone.

NIR spectroscopy is routinely carried out industrially using large-scale equipment for quality control of food and pharmaceutical products, for example. Specialized analysis software can then be used to measure aspects such as water content or the content of proteins and fats. Installed in a smartphone, this measurement technology will one day also provide useful information to consumers about the invisible properties of their food.

Analyzing food with a smartphone happens in just a few seconds, without compromising the product in any way. In certain cases, the NIR sensor

(Continues on p. 10)

Water-pollutant-removal technology extended to phosphorus

A project has been announced to demonstrate Microvi's (Hayward, Calif.; www.microvi.com) pollutant-removal-and-recovery technology for phosphorus in water. The objective of the demonstration is to reduce total phosphorus levels to 0.1 mg/L at a wastewater treatment plant. The nine-month project is a collaboration between Microvi, U.K.-based Southern Water Ltd., WesTech Engineering, Inc. and the University of Portsmouth.

Current methods for phosphorus removal from wastewater rely on dosing high levels of expensive metal salts, Microvi says, which locks up the phosphorus and generates solid wastes with high disposal costs.

For the U.K. project, Microvi will extend the use of its MicroNiche Engineering (MNE) platform, which has previously been commercialized for converting nitrate into nitrogen in contaminated groundwater. The MNE platform works by maintaining communities of naturally occurring microbes at high densities within engineered synthetic polymer scaffolds. The microbes are chosen specifically to break down the targeted pollutant without generating sludge.

The Microvi biocatalysts, designed as a highly hydrated, hydrophillic polymer complex, mimic key fitness advantages found in natural microorganism communities while maintaining a controlled system over extended periods of time, Microvi says. The technology reduces chemical use and biosolids production in wastewater treatment, leading to reduced total costs, the company adds.

For the commercialization of NME for nitrate removal (Denitrovi technology), Microvi was recognized as a finalist for the 2017 Kirkpatrick Award for Chemical Engineering Achievement (*Chem. Eng.*, January 2018, pp. 22–28).

Another go for underground coal gasification

Leigh Creek Energy (Adelaide, South Australia; www.lcke.com.au) has received final approval from the South Australian government to start a three-month trial of underground coal gasification (UCG) at the site of the old Leigh Creek Coalfield, about 550 km north of Adelaide.

The proposed project has been a contentious issue due to environmental concerns associated with UCG. An UCG project at Chinchilla, Queensland (*Chem. Eng.*, June 2009, p. 15), operated by Linc Energy Ltd. (Brisbane, Australia; www.linceneergy.com), was banned by the Queensland government. Linc Energy (now in liquidation) was charged with causing great environmental harm at Chinchilla, releasing contaminants into the soil, air and water. It injected air into underground combustion chambers at pressures that were too high, causing the rock surrounding the coal seam to fracture and allowing the escape of toxic gases. Workers at the site reported several health issues.

The Queensland government imposed an excavation exclusion zone on more than 300 km^2 around the Linc facility where landowners were banned from digging deeper than 2 m. The zone was lifted earlier this year. Linc Energy was fined A$4.5 million (approximately $3.2 million).

In light of what happened at Chinchilla, environmental groups have been strongly opposed to the proposed Leigh Creek Energy project and disappointed by its approval by the South Australian government. However, according to Leigh Creek Energy, its proposed project is vastly different from that at Chinchilla. A detailed report by the South Australian government said "… it is unreasonable to draw an association between the two projects due to material differences related to the site suitability, operational practices and the level of regulatory oversight … the Leigh Creek site represents one of the strongest opportunities for low-risk commercial UCG anywhere in the world. On the merits of the site suitability and operational assurances, the demonstration carries minimal risk and should be approved."

The report notes that Leigh Creek Energy has used leading practices regarding well design to minimize the risk of well leakage, including the use of high temperature casing, premium gas-tight threads, high temperature cements and high temperature well heads. The company has a clear definition of the operating pressure guided by the installation of vibrating wire piezometers. The report considers the risk of fracturing due to pressurization is low.

can even be used to measure through packaging, but the application is especially useful for unpackaged and prepared foods. Other potential non-food applications for the Hertzstück detector include measuring the moisture content of skin to select the right cosmetic products, the level of active ingredients in medications or even the content of natural fibers in furniture materials.

The first spectrometers using the new infrared sensor will be available in 2019 for industrial and semi-professional applications. The average consumer will likely have access to near infrared spectroscopy in their smartphone from 2022.

CH_4/CO_2 REFORMING

Carbon dioxide reforming of methane (CRM) has received much attention, because it involves the conversion of two major greenhouse gases — CO_2 and CH_4 — into synthesis gas (syngas; CO and H_2). However, that reaction has not yet seen industrial application, because a suitable catalyst has not yet been found. Although nickel-based catalysts have some promising potential for CRM, the deactivation of nickel-based catalysts is inevitable due to metal sintering and carbon deposition.

Now, a team from the Kunming University of Science and Technology (Kunming, China; www.kmust.edu.cn) has shown that the addition of MgO plays a critical role in improving the catalytic performance of Ni supported on carbon nanotubes (CNTs) for CRM. The team's work showed that the addition of MgO strengthened the interaction of Ni and the interior surface of CNT. Highly dispersed nickel particles with small size (less than 4.5 nm) were also observed in MgO modified CNT. Also, the lifetime of the Ni-based catalyst was prolonged after adding MgO, probably due

(Continues on p. 11)

Bio-based adsorbent material removes PFAS compounds from water

Per- and polyfluoroalkyl substances (PFAS) have been widely used for high-performance fire-fighting and in the manufacture of durable goods for their chemical inertness, non-stick properties and fire resistance. They have also raised health concerns because they do not degrade in the environment, and can accumulate in the body with continued exposure.

CustoMem (London, U.K.; www.customem.com) has introduced a new method to treat PFAS from water, using its CGM, a novel bio-based adsorbent material that can selectively capture micropollutants of interest. As its first application, CGM has been optimized to capture several PFAS compounds, including perflourooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) but can also be used in other applications, such as groundwater remediation, industrial wastewater and point-of-use treatment. CGM is based on modified cellulose repurposed from agricultural waste.

CGM is seen as a complement to granulated activated carbon (GAC), which is used to remove PFAS from water, but which has performance limitations, particularly for shorter-chain PFAS species, explains Shayne Petkiewicz, CustoMem business development manager.

PFAS captured by the CGM material can be recovered, and the adsorbent regenerated, through an in-situ aqueous wash. CustoMem is currently undergoing pilot trials.

Gas-solid reaction makes efficient solar cells

The research group of Yabing Qi at Okinawa Institute of Science and Technology (OIST; Japan; https://groups.oist.jp/emssu), in collaboration with Shengzhong Liu at Shaanxi Normal University, China, has developed a simple method to fabricate thin (1 μm) perovskite films that can be used in perovskite solar cells (PSCs). Small PSCs with the thin films achieve an average power conversion efficiency (PCE) of 19.1±0.4%, with good reproducibility. Moreover, the method enables fabricating (5 × 5)-cm^2 solar modules with an active-area efficiency of 15.3%, which is equivalent to existing PSCs. The un-encapsulated PSCs exhibited an excellent lifetime (T80), exceeding 1,600 h under continuous operation in a dry nitrogen environment.

The perovskite films are made by a fast gas-solid reaction of chlorine-incorporated hydrogen lead triiodide, $HPbI_3(Cl)$ and methylamine (CH_3NH_2) gas. The resultant thick and smooth chlorine-incorporated perovskite films exhibited full coverage, improved crystallinity, low surface roughness and low thickness variation.

This study not only provides a highly reproducible method to fabricate PSCs and modules with enhanced efficiency and stability — keys for their commercialization — but also gained an in-depth understanding for the underlying mechanisms responsible for device stability improvement.

A bi-functional catalyst enables one-step, 'tunable' F-T synthesis of liquid fuels

An integrated catalytic process for the direct, Fischer-Tropsch (F-T) conversion of synthesis gas (syngas) into different types of liquid fuels, without subsequent hydro-refining post-treatments of F-T waxes, has been developed by the research group of professor Noritatsu Tsubaki at the University of Toyama (Japan; www.u-toyama.ac.jp), in collaboration with the National Institute for Materials Science (NIMS) and Chinese University. Selectivities for gasoline (74%), jet fuel (72%) and diesel fuel (58%) have been achieved using mesoporous Y-type zeolites with a precisely controlled steric nanostructure, mesoporous structure and acidity distribution, in combination with 10-nm-dia. cobalt nanoparticles and 0.4-nm-dia. lanthanum particles. The researchers were able to reduce the amount of the rare-earth metals to one third the amount needed by previous efforts.

The types of liquid fuels produced can be readily tuned by controlling the porosity and acid properties of the zeolites. Also, a new product-distribution model was constructed for the bifunctional catalysts, which do not obey the traditional Anderson–Schulz–Flory (ASF) distribution. In addition to providing a simple, direct method for synthesizing different types of liquid fuels, the researchers believe that the catalyst system may also be suitable for producing jet fuel from CO_2 and H_2, without the need for biomass feedstock.

The achievement is a follow-up of a five-year project to develop F-T jet fuel from biomass, which began in 2012, with collaboration from the Tsubaki group, Mitsubishi Heavy Industries Group and JXTG Nippon Oil & Energy Corp., and support from the New Energy and Industry Technology Development Organization (NEDO). A demonstration plant is planned to be built within the next three years.

Printing 2-D piezoelectric materials for sensors and energy harvesting

A new, inexpensive method to print large-scale sheets of two-dimensional (2-D) piezoelectric material has been developed by a team from RMIT University (Melbourne, Australia; www.rmit.edu.au) led by professor of electronic engineering Kourosh Kalantar-zadeh (now a professor of chemical engineering at the University of New South Wales (Sydney, Australia; www.unsw.edu.au)). The method is simple, scalable, low-temperature and cost-effective, and significantly expands the range of materials available at such scales and quality, offering the opportunity for new piezosensors and energy harvesting.

Until now, no 2-D piezoelectric material has been manufactured in large sheets, making it impossible to integrate into silicon chips or use in large-scale surface manufacturing. The new inexpensive process allows integrating piezoelectric components directly onto silicon chips. The RMIT University team has produced large-scale (several centimeters), wide-bandgap, 2-D gallium phosphate ($GaPO_4$) nanosheets of unit-cell thickness.

Gallium phosphate is a quartz-like crystal used in piezoelectric applications such as pressure sensors and microgram-scale mass measurements, particularly in high temperatures and harsh environments. Because it does not naturally crystallize in a stratified structure and hence cannot be exfoliated using conventional methods, its use has been limited to applications that rely on carving the crystal from its bulk.

The nanosheets are made by a two-step process. The first step involves exfoliating gallium oxide from the surface of liquid gallium — made possible by the lack of affinity between the oxide and the bulk of the liquid metal. The second step involves printing that film onto a substrate and transforming it into 2-D gallium phosphate via exposure to phosphate vapor.

A one-step solution for remediating two challenging groundwater contaminants

A research team from the New Jersey Institute of Technology's (NJIT; Newark, N.J.; www.njit.edu) Department of Chemistry and Environmental Science has discovered a new bacterium that may help to alleviate concerns about two of the most pervasive and toxic groundwater contaminants — 1,4-dioxane and 1,1-dichloroethylene (1,1-DCE). A common industrial solvent, 1,4-dioxane is frequently found concurrently with 1,1-DCE in groundwater. The combination of these two chemicals makes environmental remediation especially daunting, since they react very differently to treatment solutions and often require two separate remediation techniques, driving up the costs and complexity of groundwater treatment. Compounding the problem, 1,1-DCE has been shown to contribute to 1,4-dioxane's resistance to traditional treatment methods. However, the new bacterium discovered by NJIT is said to be the first remediation method capable of simultaneous biodegradation of both 1,4-dioxane and 1,1-DCE.

The new bacterium, known as DD4, was first discovered in activated sludge samples from a municipal wastewater-treatment facility. In field tests, DD4 was shown to degrade a sample containing 10 parts per million (ppm) of 1,4-dioxane down to just 0.38 parts per billion (ppb). Additionally, the concentration of 1,1-DCE in the sample was reduced from 3 ppm to less than 0.02 ppm. The new bacterium also shows promise in halting 1,1-DCE's inhibition of other bacterial degradation methods for 1,4-dioxane.

Moving forward, the NJIT team hopes to continue characterization of DD4 to better understand its enzymatic activity. They see much promise in DD4's application into larger-scale groundwater-remediation processes, due to several contributing factors. According to NJIT, unlike other bacterial treatments, DD4 does not aggregate in water, but rather disperses freely, enabling remediation of larger sites. Also, DD4 is said to culture rapidly and remain stable and viable over several days under normal refrigeration conditions, simplifying logistics for its delivery to remediation sites. ■

to the stabilization and dispersion of Ni particles and the restraint on the gasification of CNT.

DIGITALIZED QC

Last month, Daikin Industries, Ltd. (Osaka, Japan; www.daikin.com) and Hitachi, Ltd. (Tokyo, Japan; www.hitachi.com) started a joint demonstration to digitalize quality control (QC) know-how in the reaction process of chemical manufacturing, especially in fluorochemicals, at Daikin Yodogawa Plant in Settsu, Osaka Prefecture. For this joint demonstration, Daikin and Hitachi will introduce a system that generates alarms for workers to ensure appropriate QC instantaneously. Hitachi's Lumada image-analysis technology enables workers to visualize a number of statuses in reaction processes, such as liquid foaming status and color change, all of which were previously checked visually by workers at certain designated points. This digitalization technology extracts the operating status data instantaneously and consecutively, which leads to maintaining QC and improving efficiency in the future.

Daikin and Hitachi advance their collaborative creation to achieve a next-generation production model utilizing advanced internet of things (IoT). From the perspective of the 4Ms (man, machine, material and method), they have collected the time-series numerical values and image data of the reaction statuses of chemicals (liquid color and foaming) and equipment operation statuses (temperature and rotating speed) using cameras and sensors. By converting the image data to numeric data and correlating them with quality, it has become possible to establish quantitative criteria that affect the quality of finished products. Because of the criteria, the two companies gained the prospects of reducing defective rate and improving productivity, and are now beginning a joint demonstration within the fluorochemicals-manufacturing process.

In this demonstration, Daikin and Hitachi will introduce the system on-site to verify the effects. In the future, the system will be enhanced by adding new factors of logic through monitoring and analyzing human-decision. This system will contribute to digitalize the manufacturing know-how of skilled, expert workers. ❑

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Plant Watch

Covestro to invest €1.5 billion in new, world-scale MDI plant in Baytown

October 9, 2018 — Covestro AG (Leverkusen, Germany; www.covestro.com) approved an investment of around €1.5 billion to build a new methylene diphenyl diisocyanate (MDI) plant in Baytown, Tex. This investment at the existing site in Baytown is the largest single investment in the history of the company. Total capacity of the new train will be 500,000 metric tons per year (m.t./yr) of MDI, and production is expected to begin in 2024. Covestro also plans to double its MDI production capacity in Brunsbüttel, Germany from 200,000 to 400,000 m.t./yr in 2019. At the same time, an older, 90,000-m.t./yr MDI unit will be closed.

Non-phthalate plasticizer capacity to be added in 2019, Perstorp says

October 9, 2018 — Perstorp (Malmö, Sweden; www.perstorp.com) will substantially expand the production capacity of its non-phthalate polyester plasticizer Pevalen in 2019. To accomplish this, Perstorp has entered into a longterm production agreement with Italian company Alcoplast Srl. The new partnership more than doubles the current production capacity, bringing it to a total of 50,000 m.t./yr. Additionally, plans to further increase the production capacity beyond 100,000 m.t./yr are advancing and will be timed to meet future market demand.

Saudi Aramco and Total launch studies to build petrochemical complex in Jubail

October 8, 2018 — Saudi Aramco (Dhahran, Saudi Arabia; www.saudiaramco.com) and Total S.A. (Paris, France; www.total.com), signed a joint development agreement for the front-end engineering and design (FEED) of a giant petrochemical complex in Jubail, Saudi Arabia. The world-class complex will be located next to the Satorp refinery, operated by Saudi Aramco (62.5%) and Total (37.5%). It will comprise a mixed-feed cracker (50% ethane and refinery off-gases) with a capacity of 1.5 million m.t./yr of ethylene and related high-added-value petrochemical units. The project represents an investment of around $5 billion and is scheduled to start up in 2024.

Hexcel opens combined precursor and carbon-fiber plant in France

October 5, 2018 — Hexcel Corp. (Stamford, Conn.; www.hexcel.com) has officially opened its new plant at the Les Roches-Roussillon Chemicals Industry Platform in Isère, France. The new 37-acre plant is the company's first combined precursor and carbon-fiber plant outside the U.S. Hexcel invested around €200 million in the plant.

Sumitomo completes new methionine plant in Japan

October 5, 2018 — Sumitomo Chemical Corp. (Tokyo; www.sumitomo-chem.co.jp) completed its new production line for feed-additive methionine in Niihama City, Ehime Prefecture, Japan. The production capacity of the new line is approximately 100,000 m.t./yr, which brings Sumitomo Chemical's total production capacity for methionine to approximately 250,000 m.t./yr, including existing facilities.

Ineos Phenol to expand production capacity in Mobile, Alabama

October 3, 2018 — Ineos (London; www.ineos.com) announced that Ineos Phenol is planning to expand the capacity of its plant in Mobile, Ala. up to 850,000 m.t./yr, making it the largest phenol-production unit in the world. Phenol products are used in a diverse range of end markets, including the automotive, construction, electronics and fiber industries.

ExxonMobil starts producing ultra-low-sulfur fuels at new Beaumont unit

September 28, 2018 — ExxonMobil Corp. (Irving, Tex.; www.exxonmobil.com) said that a new unit at its integrated Beaumont, Tex. facility has started operations, increasing production of ultra-low-sulfur fuels by about 45,000 barrels per day (bbl/d). The new unit relies on a proprietary catalyst system that removes sulfur while minimizing octane loss.

Mitsui to construct U.S. production plant for glass-fiber-reinforced polypropylene

September 24, 2018 — Mitsui Chemicals, Inc. (MCI; Tokyo; www.mitsuichem.com) will set up a new production facility for long glass-fiber-reinforced polypropylene (LGFPP) at the Ohio plant of its U.S. subsidiary, Advanced Composites, Inc. The new plant is expected to have a capacity of 3,500 m.t./yr of LGFPP. The site is slated for completion in Sept. 2019, with operations commencing in Oct. 2019.

Inovyn to raise PVC production in Belgium

September 24, 2018 — Inovyn (London, U.K.; www.inovyn.com) intends to increase production of general-purpose polyvinyl chloride (PVC) at its Jemeppe site in Belgium. The new investment, which will add another 200,000 m.t./yr of capacity at the site, is set to be operational in 2020.

Mergers & Acquisitions

Celanese to acquire engineering thermoplastics compounder in India

October 12, 2018 — Celanese Corp. (Dallas, Tex.; www.celanese.com) agreed to acquire Next Polymers Ltd. (Mumbai, India), one of

India's largest domestic engineering thermoplastics (ETP) compounders. Next Polymers specializes in custom compounding of various ETP materials and operates a production facility in Silvassa, India, with a capacity of 20,000 m.t./yr. Celanese expects to complete the transaction in the first quarter of 2019.

Total and Sonatrach form joint venture for polymers project in Algeria

October 10, 2018 — Total and Sonatrach (Algiers, Algeria; www.sonatrach.com) have signed a shareholder agreement to create a joint venture (JV) known as STEP (Sonatrach Total Entreprise Polymères). STEP will be responsible for carrying out a joint petrochemical project in Arzew, western Algeria that includes a propane dehydrogenation (PDH) unit and a polypropylene production unit with an output capacity of 550,000 m.t./yr.

Cabot acquires NSCC Carbon from Nippon Steel Carbon Co.

October 3, 2018 — Cabot Corp. (Boston, Mass.; www.cabotcorp.com) has acquired NSCC Carbon (Jiangsu) Co. from Nippon Steel Carbon Co. The group owns a 50,000-m.t./yr carbon-black manufacturing facility in Pizhou, China, which was originally commissioned in 2015. Acquisition of this plant will support Cabot's specialty carbons product line within the Performance Chemicals segment.

Ineos to acquire the chemicals intermediates business of Flint Hill Resources

October 3, 2018 — Ineos Enterprises (London; www.ineos.com) has entered into a binding agreement to acquire the chemical intermediates business of Flint Hills Resources, LLC (Wichita, Kan.; www.fhr.com). The deal is expected to be complete by the end of 2018, subject to regulatory approval. The acquired business comprises production facilities for purified isophthalic acid (PIA), trimellitic anhydride (TMA) and maleic anhydride (MAN) located near Chicago, Ill.

BASF and LetterOne sign agreement to merge Wintershall and DEA

September 28, 2018 — BASF SE (Ludwigshafen, Germany; www.basf.com) and LetterOne Group (Luxembourg; www.letterone.com) signed a definitive transaction agreement to merge their respective oil-and-gas businesses in a joint venture (JV), which will operate under the name Wintershall DEA. Closing of the transaction is expected in the first half of 2019. BASF will initially hold 67% and LetterOne 33% of Wintershall DEA's ordinary shares.

Westlake Chemical plans to acquire French compounding company

September 25, 2018 — Westlake Chemical Corp. (Houston; www.westlake.com) has offered to acquire Nakan, a compounding solutions business headquartered in Reims, France. Nakan has eight production facilities, located in China, France, Germany, Italy, Japan, Mexico, Spain and Vietnam, as well as a research facility in France and an application laboratory in the U.S. Nakan's products are used in the automotive, building and construction and medical industries.

Mary Page Bailey

The Old Art of Brewing Looks Forward

Research and development in the brewing industry is peaking, driven by efforts to improve quality, efficiency and sustainability

IN BRIEF

Within the chemical process industries (CPI), the brewing industry is among the sectors with the deepest historical roots and the most entrenched traditions. While modern brewers are by no means turning their backs on traditional beer making (see box, p. 16), they are increasingly looking forward, relying on advanced science and engineering in never-before-seen ways.

"Research and development in brewing may be peaking now, after a period of decline in the 2000s," says Kevin Verstrepen, director of the the Leuven Institute for Beer Research (LIBR) at Leuven University (KU Leuven; Belgium; www.libr.be).

Technology advancements are allowing brewers of all sizes to pursue improved efficiency and sustainability and find ways to differentiate their products in a crowded and competitive marketplace.

"There is a lot of pressure on brewers to keep coming up with new products with different taste characteristics, and also a large push to reduce resource use, such as water and energy, in the brewing process," says Brandon Smith, engineering manager with Sierra Nevada Brewing Co. (Chico, Calif.; www.sierranevada.com).

Francesco Meneguzzo

FIGURE 1. A brewing method based on controlled hydrodynamic cavitation could save energy and time in the brewing process

Optimizing brewing yeast

Beer would not be beer without yeast to ferment the sugars from grain into ethanol. But brewer's yeast, the single-celled organism *Saccharomyces cerevisiae*, is a broad classification that encompasses several hundred yeast strains. Yeast is important not only for generating the ethanol in beer, but also for imparting flavors to the drink, through the fermentation byproducts they produce. "I think the most active area of innovation [in the brewing industry] is in the microbiology, and in the fermentation step of the process," says Verstrepen.

Fermentation is quickly evolving, Verstrepen says, driven by brewers' desires to improve the quality of their products and the efficiency of their processes "If you can ferment faster or generate higher levels of alcohol, you can use less energy, lower chemical volumes or brew more beer using the same resources," he says.

"In the past, beer has been brewed with what is really sub-optimal yeast — brewers had to kind of learn their way around the yeasts' limitations," Verstrepen says. "But now, using microbiology tools, we are much more able to develop yeast variants that are geared toward certain criteria." Scientists like those at the LIBR are now able to engineer variants of yeast to better control the metabolic products that create unique flavor profiles in beer. "This is a major evolution in brewing," Verstrepen says.

Vestrepen's laboratory has used genetic sequencing to build a collection of yeast variants and to map how the variants are related — a "family tree" of brewer's yeast. And it is now using that information to create cross-species hybrids yeast in a search for variants that give rise to a new flavor mix. "Often, traditional brewers don't know what their yeast really is," Vestrepen says, so we work to identify the exact strain or mix of strains.

Yeasts reproduce sexually by combining spore cells, he explains, and "we now have micromanipulation techniques to generate

yeast variants that we want to try in brewing." This includes the use of *Brettanomyces* and wild yeast species, in addition to the traditional *Saccharomyces* strains. Vestrepen uses the analogy of wolves and dogs to describe wild yeast species and brewer's yeast. "Brewer's yeast has been domesticated," he says. "Wolves are to dogs what wild yeast is to regular brewer's yeast. We've had some success generating hybrids between wild strains and domestic ones."

Screening of the resulting variants remains somewhat of a bottleneck, but the speed at which researchers can test them has been accelerating. "We are taking advantage of robotics advances and 'lab-on-a-chip' technologies to sort and screen the resulting variants," Verstrepen says. "There's also microdroplet technologies that allow us to ferment tiny volumes very quickly to test whether a variant produces the desired by products and has the desired properties."

Engineering flavor

Knowledge about what influences beer flavor has been available for a long time, "but to an unprecedented degree, we are becoming able to connect specific compounds with the aromas and tastes as perceived by humans," Vestrepen says, using machine learning and advanced analytical chemistry. Using gas chromatography/mass spectroscopy (GC/MS) and high-performance liquid chromatography (HPLC), among others, "we are learning how individual flavor compounds influence each other when combined into a finished beer."

A typical project for LIBR would involve selecting yeast variants that produce a specific desired flavor pattern. For example, Vestrepen's lab worked with a Canadian brewery to breed a strain capable of producing more acetate esters, which produce fruity aromas in the resulting beer. Many projects in Vestrepen's lab are surrounded by company trade secrets, so no specifics can be discussed.

Meanwhile, at the University of California at Berkeley (www.berkeley.edu), work was recently published by a group of scientists aimed at eliminating the need for hops in beer brewing and replacing them with flavor chemicals produced by yeast. Hops are relatively expensive and require a significant amount of water and fertilizer to grow. Also, the crop can vary in the levels of flavorful oils it contains. Genetically engineered yeast may be able to produce the chemicals responsible for hoppy flavor. A recent paper in *Nature Communications* describes work by Charles Denby and Rachel Li in which they used the gene-editing technology known as CRISPR-Cas9 to introduce genes from mint and basil plants into yeast strains. The genes code for enzymes that produce the flavor components linalool and genaniol, two components of beer's hoppy flavor. The duo has formed a company to offer "hoppy" yeast to brewers.

In addition to looking for novel flavor characteristics, the search is on for yeast variants that ferment at lower temperatures, yeasts that allow beer to retain peak flavor longer, or those that can be used for low-gluten beer and no-alcohol beer, notes Sierra Nevada's Smith. And brewers and scientists are also looking beyond yeasts to bacteria in an effort to generate new varieties of beer known as "sour beers." This is an area that is becoming more popular and a fertile ground for new beer types, says Smith. A number of researchers and brewers are working with *Lactobacillus* species to produce lactic acid in the fermentation process. This results in beers with a tart, sharp flavor.

Alongside the yeast cells themselves, brewers are looking to improved monitoring of fermentation in an effort to better control flavor. For example, a recent innovation involves acoustic-based sensors that measure changes in the density of the fermentation broth during the process. The sensors, developed by TZero Labs (State College, Pa.; www.tzerolabs.com), work like a sonogram, detecting changes in the speed at which sound waves travel through the liquid. Because these changes are tied to progress of fermentation (consumption of sugar and production of ethanol change the fluid density), the sensors can tell

BEER BREWING BASICS

Although hundreds of beer types exist, most are variations using only four basic ingredients: barley, water, hops and yeast. The process begins with barley (although other grains can be used to brew beer) the grains must be milled to crack open the grain husks, but brewers must modulate the milling so that the cracked husks are still intact enough to serve as a filter bed later. The milled barley, known as grist, enters a mash turn, where the milled barley is mixed with water and heated. In the heated water, enzymes from the milled grain convert starches in the grain into fermentable sugars. The mash stage creates a solution of sugars and water, known as wort, and spent grain, which must be separated by lautering, in which solids from the mash settle and form a filter bed over a perforated surface, through which the wort is collected. The wort is heated to halt enzyme activity and condense the liquid. At this stage, hops are added to flavor the beer and add the desired bitterness. Next, the wort enters a fermentation tank, where yeast is added. The yeast converts sugars in the wort to ethanol and releases carbon dioxide. Yeast also produces byproducts, which impart different flavors. The beer is then carbonated using high-pressure CO_2, and bottled (or canned). ❑

brewers about fermentation starting point, ending point and progress without the need for any manual measurements, explains Stephen Wells, co-founder of Tzero Labs. As part of a broader automation solution offered to microbreweries by partner BoxcarCentral, the sensors allow remote monitoring of fermentation processes. The retrofittable sensors fit into sanitary ports in fermentation tanks and can replace hydrometers. The sensors are also starting to be used to monitor the fermentation rate by detecting the formation of carbon dioxide bubbles in the tank. This, combined with its precise ability to measure temperature, allows brewers to investigate how small temperature adjustments can affect yeast activity and flavor.

Resource conservation

While beer taste and quality are rightly at the forefront of technology development, all brewers are also constantly trying to identify ways to lower energy consumption and resource use in the brewing process. Here, one of the largest companies in the brewing space, Anheuser Busch InBev (AB InBev; Leuven, Belgium; www.ab-inbev.com) has developed technology that allows the wort-boiling step to be carried out at below boiling temperature, reducing total energy use by 10% and lowering water use by 2–3%. Elevated temperature and bubble formation in the wort-boiling step are essential for some of the many chemical and physical transformations that occur there, according to David De Schutter, Innovation and Technology Development Director in Europe for AB InBev. "We carefully maintain the temperature at 1°C below the boiling point, which allows the temperature-dependent transformations to happen," De Schutter explains, "and we introduce sparging gas [either N_2 or CO_2] using spray balls to mimic the bubbles you would see at boiling temperatures." This achieves the objectives of the wort-boiling with lower energy use and less water evaporation. The process was developed at AB InBev's Global Innovation and Technology Center (GITeC) and has now been implemented in several locations. AB InBev is validating the process for its other brands, De Schutter says. The lower-temperature process is part of a wider global sustainability effort by AB InBev to reduce carbon emissions across its supply chain by 25% by 2025. AB InBev is open to licensing agreements for the technology, and is offering free licenses to small brewers, De Schutter says.

In a more drastic shift in process approach, also aimed at energy and time savings, researchers Lorenzo Albanese and Francesco Meneguzzo, at the Institute of Biometeorology of the National Research Council (CNR; Florence, Italy; www.ibimet.cnr.it) have developed a controlled hydrodynamic cavitation technique in early process steps prior to the fermenting step. The cavitation is designed to replace the need for dry-milling the grain and boiling the wort in a traditional process. Known as Cavibeer Technology (www.cavibeer.com), the

LLNL

FIGURE 2. Silicone microcapsules of sodium carbonate could allow CO_2 capture at lower costs

technique, jointly patented by CNR and the private company Bysea S.r.l., works by pumping the water-grain mixture through one or more specialized Venturi tubes, where the fluid accelerates and the hydraulic pressure drops due to Bernoulli's principle (in fluid dynamics, an increase in fluid speed results in decreased pressure). The Venturi tubes are small (tenths of centimeters in length), and a careful design is crucial, the researchers say. The pressure drop through the tubes results in the formation of a large amount of micro- and nanoscale vapor-filled bubbles, which then implode when the pressure recovers downstream after a few milliseconds.

The implosion of the bubbles creates extreme releases of energy at the microscale, and it is this energy that can be harnessed for mechanical effects, such as breaking the solid grains, and for accelerating the release of sugars from the grain. Used early in the process, the cavitation renders unnecessary the dry milling of the grains, and raises the extraction of enzymes and starches from the malt. Also, saturated fatty acids are partly burned inside the collapsing bubbles, favoring foamability in the finished beer. When used later, after mashing-out and during hopping, cavitation increases the efficiency of extraction of the hops chemicals responsible for beer's bitterness, as well as of valuable biocompounds capable of boosting the beer's shelf life. Albanese and Meneguzzo say that the use of controlled cavitation can reduce the energy required for brewing by at least 40% and realize time savings of 60% or more. By tuning cavitation, even the gluten content can be reduced down to the gluten-free threshold without adding chemicals,

the scientists say.

The two researchers have set up a pilot system (250 L) to test the cavitation process and have installed an industrial-grade cavitation brewing process (12 hectoliters), constructed by the partner company GBL S.r.l., at the San Gimignano Brewery in Barberino Val d'Elsa, Italy.

The Cavibeer team spent considerable effort in optimizing a mash filtration unit and taking steps to reduce the noise to the current insignificant levels. The industrial-grade plant is now fully reliable and scalable up to at least 200 hL. Currently, several beer recipes and styles are being tested and tasted at the San Gimignano Brewery.

Utilizing CO_2 products

Brewing inescapably generates significant amounts of carbon dioxide as the product of fermentation. Since this gas is also needed for carbonation and gas purging in the beer process, it also presents opportunities to brewers.

"The CO_2-reuse opportunity is huge for breweries," both from an efficiency standpoint and an environmental one, says Ryan Reid, an independent engineering consultant with a portfolio of craft brewing clients. "However, right now, CO_2 reclamation only makes economic sense for the largest brewers because collecting it, purifying it, pressurizing it and storing it is very capital-intensive." But the costs are creeping steadily downward, Reid says, and it may become economically viable for smaller operations in the future.

One researcher who may help lower the cost of CO_2 capture at breweries is Congwang Ye, a research and development engineer at the Lawrence Livermore National Laboratory (LLNL; Livermore, Calif.; www.llnl.gov). Ye has developed silicone microcapsules containing a solution of sodium carbonate (Figure 2) that adsorbs CO_2 gas. Although the original conception targeted CO_2 capture from power-plant exhaust gas, the microcapsules could theoretically collect CO_2 coming from fermentation tanks. The microcapsules release the gas at elevated temperatures, so the microcapsules could be reused. "Normally, Na_2CO_3 adsorbs CO_2 slowly, so it's not used as a capture vehicle, but encapsulating the Na_2CO_3 inside a silicone shell dramatically raises the contact area with the gas, so the capture efficiency goes way up," Ye says. The microcapsules are made from a benign silicone that is safe for a food process. The LLNL team is also working on a new method for making uniform microcapsules at larger scale.

For the brewing sector, Ye envisions onsite collection of CO_2 and piping the gas to a geographically central hub facility near a network of breweries. There, it would be concentrated, purified and re-used by the breweries. A more compact modular unit that allows onsite reclamation is also in the plan to further reduce the cost. Because the microcapsule-based scheme is efficient and much less capital-intensive, it could be a solution for a wider swath of the brewing industry, Ye says. ■

Scott Jenkins

For more on water management in brewing, view the online version of this article at www.chemengonline.com.

Engineering Challenges? There's an App for That

Mobile applications for the CPI simplify process engineering challenges and enhance plant optimization

IN BRIEF

ENGINEERING AND DESIGN CHALLENGES

IMPROVING OPERATIONS VISIBILITY

ANALYTICS FOR PLANT OPTIMIZATION

Most everyone recalls the Apple tagline boasting, "There's an app for that." It appears Apple was ahead of its time; today, there really is an application (app) or online tool for just about everything, and the world of chemical engineering is not excluded. Mobile engineering apps and online tools exist to help simplify process engineering, provide visibility into systems and optimize asset and plant health. Some of the engineering apps currently finding use in the chemical process industries (CPI) are explored in this article, so read on and it's likely you will find that there really is an app for the tasks you're looking to simplify.

Alfa Laval

FIGURE 1. Explore from Alfa Laval is an online web tool that operates on computers, tablets and smartphones to help chemical engineers investigate whether centrifugal separation is a suitable technology for a specific separation problem

Engineering and design challenges

Designing processes and systems can be one of the more challenging tasks in the CPI, so tools that help simplify the task are being created. For example, Explore (Figure 1) from Alfa Laval (Lund, Sweden; www.alfalaval.com) is an online web tool that operates on computers, tablets and smartphones to help chemical engineers investigate whether centrifugal separation is a suitable technology for a specific separation problem. Tom Manelius, business development manager, Energy Separation says, "The online tool allows anyone with a case to screen data and calculate or simulate preliminary performance. The tool also guides users on how to assess key separability data and explains pilot testing with centrifuges."

Explore allows swift evaluation as to whether centrifugal separation technology would be the best way to reach target improvements in existing processes or be the best solution for separation in a new process design. "It empowers process engineers, process development people and utility managers to investigate their case on their own, rather than getting a vendor involved early in the investigations," says Manelius.

The screening is made through entering data with provided guidance that also explains suitable ranges and why these data are used in screening. Very often the most essential data for separation assessment are unknown. This is the particle or droplet size distribution, and these data are very difficult to measure in a laboratory or process, he says. "However, Alfa Laval has a very robust method to get these data from simple spin testing. This method is now shared online with video tutorials and a built-in calculation tool. The methods of how to evaluate centrifugal technology are well established, but have never been readily available to the industry in an easy format," says Manelius. "Not only is it now available, but the case can be saved and shared with colleagues, labs and suppliers to facilitate the overall process."

Designing a heat-trace system can likewise be tricky, so Thermon (San Marcos,

Opto 22

FIGURE 2. Opto 22's groov View can be used to monitor and control automation systems and other components associated with plant floor equipment and process units

Texas; www.thermon.com) offers an online tool for the task. CompuTrace Express was developed to be mobile friendly and leverages the power of the company's CompuTrace Design Suite database. The online tool allows users to design a system in four steps: create the project; edit the circuit by modifying system defaults, such as changing pipe sizes, circuit lengths and insulation; create the design and, finally, generate a bill of materials.

IDEC

FIGURE 3. The WindEDIT Lite app from IDEC allows users to monitor any PLC parameter and change set points and other values. Data register, input, output, times and count values can be monitored and controlled using the standard dialog interface

"We developed this tool in response to requests for an easy-to-use solution that would address smaller heat-trace-circuit requirements — for example, systems that may be part of a larger primary heat trace system, but require new design review for proper operating temperature," says Lance Bielke, manager of

MSA

FIGURE 4. MSA offers the X/S Connect app with Bluetooth-enabled fixed gas detectors, allowing users to securely connect their devices to the detectors so they can be quickly configured

Emerson Automation Soltuions

FIGURE 5. Emerson's Plantweb Insight, enabled by wireless sensors and networks, consists of a suite of applications for analyzing plant and facility data using pre-configured algorithms, helping transform raw data into actionable insights. These applications facilitate improved decision making related to specific asset classes, components or equipment

marketing communications

CompuTrace Express can be operated on a local desktop, tablet or mobile device and the design calculations are performed in accordance with generally accepted engineering practices.

Improving operations via visibility

One of the best ways to boost plant productivity and efficiency is to view what's going on within systems and processes. Again, apps are being developed that can help do exactly that.

DeltaV Mobile from Emerson Automation Solutions (Shakopee, Minn.; www.emerson.com) allows users, such as operations managers, safety engineers and process engineers, to monitor plant functions that are of concern to them and offers collaborative features that allow streamlined workflows by making it easier for managers and engineers to share critical information, enabling enhanced business results.

"DeltaV Mobile allows users to get realtime data, not just from Emerson's DeltaV system, but from other historians and systems, as well as trends and alarms, and view operator station displays of critical control systems," explains Mariana Dionisio, DeltaV product manager, with Emerson.

Operations managers use the app to maintain visibility of operations, even when they are off site. They monitor critical process values, key performance indicators (KPIs) and alarms and receive notifications for critical alarms while communicating with other personnel. Safety engineers may monitor safety-critical data and alarms specific to plant safety, maintain situational awareness by receiving notifications and viewing alarms in real time, as well as monitoring safety-instrumented functions. Process engineers can access and view critical realtime data, alarms and trends to diagnose issues, evaluate what happened by getting alarms in context with process information, get notifications for critical alarms, even when off site, and communicate issues and troubleshoot with operators and remote experts.

According to Dionisio, DeltaV Mobile is unique in its ability to easily create views that are customized for the individual. "With other mobile solutions, engineers have to sort through a lot of information to find the information they need. With DeltaV Mobile, they can create filtered, customized lists that only show critical information that is important to them," she says. "Getting relevant information to the appropriate people allows them to make better decisions in a more efficient manner, and sharing that information with other experts in a secure, read-only, mobile environment enables them to have important information wherever and whenever they need it."

Also within a chemical facility, Opto 22's (Temecula, Calif.; www.opto22.com) groov View (Figure 2) can be used to monitor and control automation systems and other components associated with plant floor equipment and process units. Users can securely view the operator interface screens on smartphones and computers to monitor, control and troubleshoot systems while untethered from a traditional human-machine interface (HMI), says Arun Sinha, engineer, with Opto 22. Operators can also view KPIs or other process data to help improve plant operations, efficiency and safety.

The app is built in a browser and runs in a browser or in the free mobile app. It connects to Opto 22 programmable automation controls, Modbus-TCP devices, databases, online services and other data sources. "Users can drag and drop gadgets from a built-in library, then tag the gadgets to configure an application," says Sinha. "Users can also set user permissions and security, configure realtime trends up to five years, log events and set up email and text notifications."

He continues to say that groov View can add value to different departments and disciplines, such as operations, engineering, management and information technology (IT). Besides levels of access, the app can be configured to have separate user groups access only the information pertinent to them for their job function. "For example, operations technicians could be exposed to process and sensor level data, engineers to production data, IT to network perfor-

Voith Digital Soluitons

FIGURE 6. Voith's OnCumulus is a cloud-based industrial internet of things (IIoT) platform that uses an open and agile philosophy for rapid development, deployment and integration with other third-party enterprise systems and data sources to leverage data from sensors and instrumentation to support the objectives of the organization

mance information and management to overall business-related data from within the plant, as well as outside sources," explains Sinha.

Another app designed for better visibility is IDEC's (Sunnyvale, Calif.; www.us.idec.com) WindEDIT Lite app (Figure 3), which provides two-way access to its family of MicroSmart FC6A PLCs. Don Pham, senior product marketing manager at IDEC, says: "With the WindEDIT Lite app, users can monitor any PLC [programmable logic controller] parameter and change set points and other values. Data register, input, output, times and count values can be monitored and controlled using the standard dialog interface. The app also has a custom dialog interface, which the user can configure to allow only certain PLC parameters to be monitored and controlled. Trending is supported within the app, with users able to plot multiple register points for graphical views."

The app provides access to an SD memory card installed in the PLC, so logged information stored in the memory card can be easily accessed. The app is often used by plant operators, maintenance techs and engineers to perform various tasks. For example, if a plant operator needed to send production status to the plant manager at the end of a shift and to store these data in a historian, he could use the app to retrieve the logged data from the MicroSmart FC6A PLC via Bluetooth and then attach the logged data to an email and send it to the plant manager and a cloud-based historian via Wi-Fi. Maintenance techs can use the app to interact with the PLCs as required. Also, engineers can use the app to monitor key PLC parameters and make adjustments as necessary to keep each parameter within its target range.

Also using Bluetooth to enhance visibility, MSA (Lake Forest, Calif.; www.msasafety.com) offers the X/S Connect app with Bluetooth-enabled fixed gas detectors (the Ultima X5000 and General Monitors X5000), which allows users to securely connect their devices to the detectors so they can be quickly configured (Figure 4).

"Workers can see the status at a glance on their mobile device, change alarm set points and relay options and check the status of the last calibration, including 'as found' and 'as left' values," says Carrie DuMars, product line manager, Detection.

The app is helpful for maintenance and instrument technicians faced with tending gas monitors located in difficult-to-reach locations or crowded equipment areas near piping, valves and other installed equipment where gas leaks can potentially occur. "With the X/S Connect app, workers no longer need to perform ladder climbs, stand on temporary scaffolds or work in awkward positions to perform routine gas detector tasks on these monitors," DuMars says. "Wirelessly accessing the gas monitors from up to 75 ft away enables safety and convenience and the realtime availability of the gas detector data helps workers rapidly set up, operate and maintain the equipment for better efficiency and use of their time."

Analytics for plant optimization

Asset health is essential to efficient processes, so knowing and analyzing exactly what's happening with assets is key to plant and process optimization. Fortunately there are apps for that, too.

Emerson Automation Solutions offers its Plantweb Insight and Plantweb Optics for this purpose. "Plantweb Insight [Figure 5], enabled by wireless sensors and networks, consists of a suite of applications for analyzing plant and facility data using pre-configured algorithms, helping transform raw data into actionable insights. These applications facilitate improved decision making related to specific asset classes, components or equipment," explains Brian Joe, wireless product manager. "The app is designed to help maintenance, reliability, safety and energy personnel improve overall operations."

He says the app accesses process equipment data from key assets from numerous sources, including wireless devices and OPC UA servers. "By providing realtime analytics on important plant assets, such as pumps, heat exchangers, steam traps and pressure-relief valves, actionable information is created and used for predictive maintenance and proactive approaches, enabling faster decision making to help facilities improve operational performance. Timelier and educated decisions can be made on equipment to help extend asset life and reduce downtime, as well as reduce excess energy use and emissions. Manual inspection rounds can also be reduced or eliminated with the help of these apps."

Emerson's Plantweb Optics is an asset performance platform that centralizes data from different asset sources to provide a holistic view of asset health in a view that is customized to deliver what is relevant to personnel, such as safety engineers, plant managers or maintenance managers, in a relevant context, says

Mani Janardhanan, vice president, Plantweb, with Emerson.

It aggregates data from various predictive intelligence applications to create a holistic picture of asset health and make that available anytime and from anywhere. Plantweb Optics combines the data from multiple applications into asset-centric information, and then delivers personal-based alerts and KPIs for improving the reliability of rotating equipment, instruments and valves. The latest iteration of the app allows collaboration and can be integrated with enterprise resource planning (ERP), SAP or a computerized maintenance management system (CMMS) systems to create work orders.

In a similar vein, Voith Digital Solutions (York, Pa.; www.voith.com) offers OnCumulus (Figure 6), a cloud-based industrial internet of things (IIoT) platform that uses an open and agile philosophy for rapid development, deployment and integration with other third-party enterprise systems and data sources to leverage data from sensors and instrumentation to support the objectives of the organization, says Brent Ward, solutions expert. "For example, in some chemical operations, sensors can monitor flow, temperature, pressure and other parameters to detect anomalies in the operation before they lead to failure. Additionally, process parameters are monitored against the desired outcomes/output and are then used to generate a virtual sensor that can be used to further monitor and optimize the process," says Ward.

The app also provides some basic tools for data visualization, monitoring, dashboarding and alerting. Voith has included a "coordinator" feature to capture the best practices for checklists of items, diagnostics processes, maintenance procedures and other routine items that help save significant time, materials and scheduling. "Most importantly, Voith's cloud architecture enables the development and use of advanced analytics that allow for optimized algorithms and machine learning across equipment and facilities," says Ward. "This forms the foundation for leveraging learning at a global scale."

The app is intended to improve plant operations by visualizing the data, having a central source of data and providing access to comparative data across operations. "At a deeper level, advanced analytics and algorithms can directly impact efficiency of operations, such as energy, raw inputs, materials, identification of anomalies and early warning of failure," he continues. "And, at the deepest level, leveraging realtime and historical data across operations can support improved maintenance — proactive, prescriptive and, in the future, predictive."

The apps discussed in this article are just the tip of the iceberg. Chances are good that if there's a challenge in your chemical facility, there may be a mobile engineering app that can help solve it. ■

Joy LePree

Focus on Laboratory Equipment

Q.E.D. Environmental Systems

Hemco

Beckman Coulter Life Sciences

Markes International

Take groundwater samples with this device

This company recently acquired the Snap Sampler (photo) passive groundwater sampling technology from ProHydro, Inc. The Snap Sampler system (U.S. Patent 7,178,415) employs a unique double-ended bottle design with "snap" sealing caps that captures a sample under in-situ conditions using a simple mechanical or pneumatic trigger at the surface. The integrity of the sample is maintained all the way through analysis at the laboratory without exposure to air or potential contaminants. Samples are representative of groundwater chemistry using a simple passive sampling technique, eliminating well-purging labor and purge-water management. — *Q.E.D. Environmental Systems, Inc., Dexter, Mich.*
www.qedenv.com

Five sizes are available for this new fume hood

The new UniFlow LE AireStream Fume Hood (photo) is available with widths of 3, 4, 5, 6 and 8 ft. The LE fume hood incorporates a "unitized" superstructure, with non-metallic dual-wall construction for total chemical and corrosion resistance, strength and durability. The integral one-piece fume chamber is glass smooth with all coved corners. The AireStream baffle system with vector airflow slots directs the air through the fume chamber and through the exhaust outlet with minimum turbulence and maximum airflow efficiency, for low-flow constant-volume performance. The hoods feature a vapor-proof LED-strip light fixture and control switch pre-wired to a single-point junction box (115 V/60 Hz a.c.), and are ASHRAE-110, NFPA-45 and U.L. 1805 classified. — *Hemco Corp., Independence, Mo.*
www.hemcocorp.com

This particle analyzer has a wide dynamic range

The LS 13 320 XR particle-size analyzer (photo) is based on advanced polarization intensity differential scattering (PIDS) technology, combined with laser diffraction, which enables direct detection of particles as small as 10 nm. PIDS technology enables high-resolution measurements, and the system has a direct measurement range from 10 nm to 3,500 µm. Like the LS 13 320, the XR analyzer provides fast, accurate results, and helps users streamline workflows to optimize efficiency. Some big improvements help users reliably spot small differences that can have a huge impact on particle analysis data, says the company. The unit automatically highlights pass/fail results for faster quality control. — *Beckman Coulter Life Sciences, Indianapolis, Ind.*
www.beckman.com

A new sample preparation and concentration platform

The Centri (photo) is a fully automated multi-mode sampling and concentration platform for GC–MS (gas chromatography–mass spectroscopy) analysis. The new instrument uses market-leading robotics to reliably automate sampling and pre-concentration of volatile and semi-volatile organic compounds (VOCs and SVOCs) through all of the sample introduction modes. Analyte flows from all modes can then be concentrated on a sorbent-packed cryogen-free focusing trap, using the company's range of thermal desorption (TD) instruments. As well as enabling parts-per-trillion-(ppt) level sensitivity and allowing selective purging of interferents, such as water and solvents, the trap and valve design used in Centri allows samples to be split and re-collected onto a clean sorbent tube. — *Markes International Ltd., Llantrisant, U.K.*
www.markes.com

Oil-mist eliminators for oil-lubricated vacuum pumps

MV Oil Mist Eliminators (photo, p. 25) remove harmful oil vapors from oil-lubricated vacuum pump exhaust streams to prevent them from being inhaled by workers and settling onto furniture, walls and instruments. Featuring microfiber-glass coalescing filter elements with 0.1-µm pore size that

Note: For more information, circle the 3-digit number on p. 70, or use the website designation.

provide 99.9999% efficiency, several sizes for pumps from 5 to 300 ft^3/min are offered. Ideally suited for laboratories, research facilities and production environments, MV Oil Mist Eliminators come in four models: VisiMist (clear housing) and Midi-Mist 4-in. dia., which use one filter; the Midi-Mist 8-in. dia., which has three filters; and Maxi-Mist 10, which has five. They can also be configured to recover or recirculate costly pump fluids. — *Mass-Vac, Inc., Billerica, Mass.*
www.massvac.com

Identify materials in realtime with handheld Raman analyzer

The TacticID-1064 (photo) is a handheld Raman analyzer for realtime identification of suspicious and unknown substances in the field. It is especially advantageous in measuring difficult street samples, such as mixed narcotics, explosives and hazardous materials. It is based on third-generation 1,064-nm technology, which is a magnitude better in fluorescence elimination, lower level of detection and provides a much faster response time than predecessors, says the company. The instrument has a large and comprehensive onboard library included, but also allows users to create and import customized libraries. The TacticID-1064 displays both GHS and NFPA704 chemical safety information, giving additional actionable data. — *B&W Tek, Newark, Del.*
www.bwtek.com

A mini bioreactor vessel for culturing adherent cells

This company recently introduced a new mini bioreactor vessel (photo, p. 26) for its ambr 250 high-throughput (ht) system. This new vessel, which is designed for optimal growth of adherent cells on microcarriers, will enable rapid, scalable cell-culture process development of vaccines. The single-use mini bioreactor for microcarrier culture has a working volume of 100–250 mL and features a single Elephant Ear impeller. This impeller type generates optimum mixing and suspension of microcarriers, allowing

Mass-Vac

B&W Tek

Sartorius Stedim Biotech

Next Advance

Torrey Pines Scientific

Bel-Art

Fritsch

adherent cells to grow over the entire microcarrier surface. The new mini vessel is based on cell culture bioreactors in the ambr 250 ht system. Utilizing this bioreactor on the ambr 250 ht system will allow rapid scaleup of optimized adherent cell culture processes to the company's Biostat STR range of pilot- and manufacturing-scale stirred bioreactors. — *Sartorius Stedim Biotech, Aubagne, France*
www.sartorius-stedim.com

A quick way to verify pipette accuracy

Checkit (photo) provides a low-cost, fast and easy way to verify the accuracy of pipettes. It is especially useful when the pipette has been dropped, cleaned or borrowed, as well as being valuable for training purposes. The Checkit can be used at the laboratory bench, and within seconds enables users to verify that the pipettes are delivering accurate volumes. This eliminates the need to read a tiny droplet's weight on a high-precision balance. Checkit is available in seven sizes from 2 to 200 µL. — *Next Advance, Inc., Troy, N.Y.*
www.nextadvance.com

A heating block controls temperature of samples

The EchoTherm Model IC50, Peltier driven, Chilling/Heating Dry Bath (photo) is supplied with a temperature probe to insert directly into the sample or into the sample block. The probe senses the sample temperature or sample block temperature directly and sends that information to the unit to drive and control the temperature exactly where set. There also is a sensor in the heater plate that allows users to set the plate temperature and use the probe to monitor the sample temperature. The Model IC50 displays and controls temperature to ±0.1°C. It can freeze, chill or heat samples from –10 to 110°C. — *Torrey Pines Scientific, Inc., Carlsbad, Calif.*
www.torreypinesscientific.com

All-in-one eye wash provides immediate first aid

Contact with acids and corrosive substances can damage the eyes after only 10 s. Having instant access to fast, safe and effective first aid can help minimize the likelihood of permanent damage and relieve irritation and discomfort from these and other foreign particles, such as dust and debris, that may enter the eye. Aero Emergency Eye Wash Solution (photo) is an all-in-one eye wash that combines sterile saline with a buffered, pH-neutralizing solution to not only rinse impurities and irritants from the eyes, but also help the eye return to a normal 7.4 pH level by quickly neutralizing corrosive chemicals. — *Bel-Art – SP Scienceware, Wayne, N.J.*
www.belart.com

This laboratory mill allows you to adjust the cutting speed

The Universal Cutting Mill Pulverisette 19 (photo) is suitable for size-reduction of a wide range of different materials due to variable adjustment of the rotational speed of the rotor, various knife geometries, replaceable blades and practical sieve cassettes, as well as being easy to clean. The high-speed version comminutes up to 60 L/h of soft to medium-hard sample materials and fibrous materials at a torque of up to 30 Nm with reliable and reproducible results. The rotational speed can be adjusted from 300 to 3,000 rpm. The low-speed version has variable rotational-speed adjustment between 50 and 700 rpm and a torque of up to 67 Nm. The combination of low cutting rate and extreme cutting forces allow a very powerful comminution of hard, tough-elastic samples and small sample quantities. — *Fritsch GmbH, Idar-Oberstein, Germany*
www.fritsch.de

Vacuum ovens in a variety of sizes

These vacuum ovens offer more usable space than similarly sized ovens. A large viewing window allows the user to quickly view their samples from a distance. The unit's controller offers "superior" temperature control and safety features, according to the company. Features include: an easy-to-read color LCD display; realtime display of measured vacuum, which helps users monitor progress of the drying sample; inert gas inlet; an interior chamber made from 304 stainless steel with a mirror polished finish; adjustable shelves for added flexibility to accommodate various size containers; exhaust-valve switching and pump switch with an electromagnetic valve controller that is safe and reliable. — *Being Instrument Inc., Riverside, Calif.*
www.beinglab-usa.com ■

Gerald Ondrey

New Products

Emerson

New thermowells reduce vibration and fatigue

The Rosemount Twisted Square thermowell (photo) is said to reduce dynamic stress, simplify process calculations and provide more accurate temperature measurements than other thermowells on the market. Twisted Square thermowells improve reliability and reduce risk of fatigue failure through their ability to dampen dynamic stresses caused by oscillating vortex pressures. These dynamic stresses can result in vortex-induced vibration (VIV), which is the primary source of thermowell stress failures. The new design is said to reduce VIV by over 90%. This helps to simplify process calculations by eliminating the need to size thermowells to reduce dynamic and frequency limits, thereby saving engineering time and lowering costs without requiring design changes. It is suitable for use where conventional thermowells fail to meet the ASME PTC 19.3 TW standard for safe and reliable thermowell design. — *Emerson, St. Louis, Mo.*

www.emerson.com

Marsh Bellofram

These flame arrestors decrease leakage and vibration risks

BelGAS FM flame arrestors (photo) stop ignited vapors from traveling backward into a vent line or tank, preventing explosions, burns and other hazards. The flame arrestor product line includes critical safety equipment, such as burner arrestors, inline arrestors, stack arrestors and vent arrestors. A key differentiator of these flame arrestors is a faceplate with a pressed and sealed sight glass, rather than one that is welded or held in place with a lock nut. This eliminates seams and gaps, reduces the chance of leaks and better withstands equipment vibration. — *Marsh Bellofram Group of Companies, Newell, W. Va.*

www.marshbellofram.com

Dräger Safety

New series of monitors expands detection for specialty gases

The Pac 6000, 6500, 8000 and 8500 personal single-gas monitors (photo) detect not only standard gases, such as carbon monoxide, hydrogen sulfide, sulfur dioxide and oxygen (Pac 6000 and 6500), but also special gases, such as ozone, phosgene and nitrogen dioxide (Pac 8000). In addition, the Pac 8500 is available with dual sensors for hydrogen sulfide/carbon monoxide or oxygen/carbon monoxide, and a hydrogen-compensated carbon monoxide sensor. This significantly reduces the influence of hydrogen on the indication of carbon monoxide. Because quick and reliable gas measurement is extremely important in an industrial environment, the Pac Series detectors provide precise results, and are easy to use. Users can choose between 18 long-life sensors for the detection of up to 33 gases. The industrial battery used in the monitors enables a service life of two years without a battery change. — *Dräger Safety AG & Co. KGaA, Lubeck, Germany*

www.draeger.com

MSA Safety

These optical flame detectors combine UV and IR sensing

The new FL500 optical flame detector (photo) is performance-approved for six different fuel sources: butane, ethane, heptane, methane, methanol and propane. By combining a precision ultraviolet (UV) sensor for quick response with an infrared (IR) sensor that monitors flame-emitted radiation, the FL500 flame detector operates at faster speeds with false-alarm immunity. The FL500 detector offers a wide field of view up to 130 deg and features three external LED indicators for local verification of normal operation, fault conditions and alarms. Designed with continuous optical-path monitoring (COPM), the detector conducts a self-check every two minutes. These optical and electrical self-check diagnostic routines ensure the sensor's optical path is clear and that the detector's electronic circuitry is operational. The operating temperature range is –67 to 185°F with a relative humidity range of 0 to 95%, non-condensing. — *MSA Safety, Cranberry Township, Pa.*

www.msasafety.com

A new technology for managing seals

This company's Viewin Technology greatly facilitates seal identification

and maintenance by providing wireless record-keeping in a mobile app (photo). Users can access relevant seal information immediately, even when equipment is running. Each ViewIn-enabled seal is equipped with RFID tags that can be read using a Bluetooth-connected RFID reader to retrieve pertinent seal information, sealing device drawings, pressure test reports, materials of construction and other supplementary items. The new technology is initially available in the company's S10 and S20 cassette seals. — *A.W. Chesterton Co., Groveland, Mass.*
www.chesterton.com


A.W. Chesterton

Online condition monitoring for turbomachinery

Machine Sentry MSO1 (photo) is a low-cost, high-speed online condition-based-monitoring (CBM) system offering realtime management of safety- and business-critical assets ranging from standard rotating equipment to advanced turbomachinery, such as power generators. The device captures critical vibration data to be stored in the Machine Sentry database, where the data can be integrated with data from other CBM techniques. The detailed CBM data can be securely accessed from anywhere in the world via a standard web browser, allowing continuous monitoring, asset management, failure detection and troubleshooting for rotating machinery. Its small size, low power consumption, Ethernet/WiFi/4G optional web connectivity, email alarm notification and high storage capability make the system easy to install, operate and maintain. Machine Sentry MSO-1 can be integrated with the Machine Sentry platform or other digital control systems, or used as a standalone platform. — *AVT Reliability Ltd., Warrington, U.K.*
www.avtreliability.com


AVT Reliability

DP transmitters for hard-to-access locations

Dwyer Instruments

The Series 629C-RS wet/wet differential pressure (DP) transmitter with remote sensors (photo) is ideal for remotely monitoring differential pressure in chillers, heat exchangers and pumps. For hard-to-access applications, the RS option of the 629C differential pressure transmit-

Aggreko North America

Itris Automation

ViscoTec Pumpen

Cole Parmer

ters comes with remote-mountable sensors, allowing users to safely monitor data. The 629C-RS option provides shielded or armored cables and is available in 10- or 20-ft lengths. Labor and material costs are reduced by connecting the high- and low-side transducers at the point of measurement, which eliminates running piping back to the transducer. — *Dwyer Instruments, Inc., Michigan City, Ind.*
www.dwyer-inst.com

Oil-free air compressors meet emissions standards

This company has released a new fleet of 100% oil-free air (OFA) compressors (photo) that are compliant with the most stringent emissions standards in North America, feature ISO class 0 air out and deliver 1,600 ft^3/min at air pressures ranging from to 55 to 150 psig. Ensuring a clean, oil-free air supply minimizes risks associated with airborne oil and contaminants, which can damage processes and decrease productivity. These air compressors are provided with this company's remote-monitoring capabilities. Performance data, alerts and service information are made available to users via the company's ARM smartphone app. — *Aggreko North America plc, Houston*
www.aggreko.com

Realtime, easy-access diagnostics for PLCs

ICS Monitoring (photo) is a realtime diagnostics solution for programmable logic controllers (PLCs). The ICS platform supports the troubleshooting of PLC-based control systems by helping to find the origin of a problem more quickly and reduce downtime. ICS Monitoring simplifies the representation of a program's data flow and logic while displaying the realtime values of the variables. This representation, featuring live values and dynamic navigation, makes troubleshooting a PLC program easier, with no need to access the development environments or to utilize a PLC code expert. Compared to other diagnostics solutions, ICS Monitoring is unique in its capacity to support a number of different PLC makes and models, says the manufacturer. The solution can connect directly to process data via Modbus TCP or OPC communication protocols, allowing data to be shared in realtime. It can also work with version-management tools to keep program information up to date. — *Itris Automation, Grenoble, France*
www.itris-automation.com

These spray dispensers are adjustable and precise

This company's new spray dispenser (photo) provides gentle and homogeneous material application, especially for dosing materials with fillers. It is based on the endless piston principle. The dispenser's spray width and spray intensity are adjustable via air pressure. Speed-dependent dosing ensures flexibility, even during the dosing process. The dispenser enables uniform surface coating with low cleaning and maintenance costs. According to the manufacturer, the new dispenser is especially well-suited for low- to medium-viscosity materials. — *ViscoTec Pumpen- u. Dosiertechnik GmbH, Töging a. Inn, Germany*
www.viscotec.de

Small-footprint drives for laboratory fluid transfer

The new Masterflex L/S variable-speed console drives (photo) sit neatly on a bench or in a fume hood in any laboratory, providing simple operation with single-turn speed control. These drives accept nine different Masterflex L/S peristaltic-pump-head types. With a flow range of 0.42 to 2,900 mL/min, it is suitable for general fluid-transfer applications. A separate power switch enables the user to maintain the speed setting when turning the drive on or off. A reversible motor makes it easy to prime or purge the tubing and pump in either direction. A remote-control feature starts and stops the unit via a connector on the back of the drive. — *Cole Parmer, Vernon Hill, Ill.*
www.coleparmer.com

Mary Page Bailey

Resistance Temperature Detectors

Department Editor: Scott Jenkins

Temperature measurement is critical in many types of process equipment, including reactors, distillation columns, furnaces, heat exchangers, evaporators, boilers and more. Among the most widely used instruments for measuring temperatures in chemical process industries (CPI) operations are resistance temperature detectors (RTDs). This one-page reference describes the principles behind the operation of RTDs, and their advantages and limitations.

RTD operation

RTDs are temperature sensors that operate on the principle that a material's electrical resistance changes with temperature in a predictable way. When an RTD is supplied with a constant current, the resulting voltage drop can be measured and the resistance calculated. The highly predictable relationship between RTD resistance and surrounding temperature allows the temperature to be determined accurately and reproducibly.

RTDs can be connected in a two-, three-, or four-wire configuration, in which current is conducted through the RTD and the resulting voltage measured. The two-wire configuration is the simplest, but also the most prone to error, because the two connecting lead wires add some resistance to the RTD (Figure 1). This introduces error. The three-wire setup is similar, except that a third wire provides compensation for the lead resistance. This requires either a three-wire compensating measurement unit or actually measuring the contribution from the third wire and subtracting it from the overall measurement. In the four-wire method, current is sourced on one set of leads, while the voltage is sensed on another set of leads to eliminate the test lead resistance from the measurement.

Temperature-sensitive materials used in the construction of RTDs include platinum, nickel and copper, with platinum being the most common. An important characteristic of an RTD material is its temperature coefficient of resistance (TCR), which determines the temperature-resistance relationship. A common industry standard is the platinum 3850 ppm/K, where the resistance of the sensor increases 0.385 ohms for each one degree-Celsius increase in temperature.

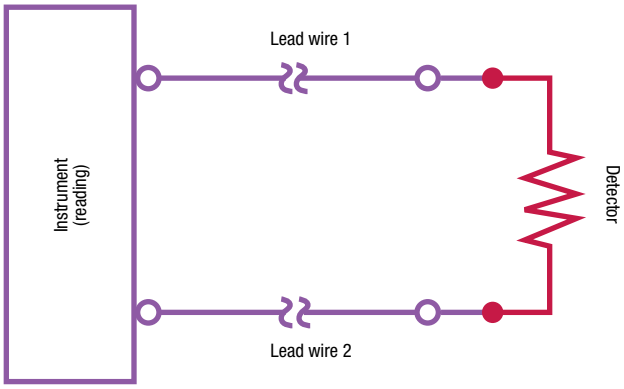

FIGURE 1. A two-wire RTD detects temperature-dependent changes in resistance, but must be corrected for resistance added by the lead wires

Physical principles

The Callendar-Van Dusen (CVD) equation is used to define the relationship between resistance (R) and temperature (T) of platinum RTDs. It is also used in the international standard IEC 60751 (International Electrotechnical Commission standard on industrial platinum resistance thermometers and platinum temperature sensors). Originally developed by British physicist H.L. Callendar, and refined by M. S. Van Dusen, the CVD equations are used to determine the temperature-resistance behavior for platinum resistance temperature detectors. The CVD coefficients A, B and C are temperature-dependent, and can be determined for a specific RTD by using calibration techniques in a laboratory. The CVD equation is shown in Equations (1) and (2).

$$R(T) = R_0[1 + AT + BT^2 + C(T - 100)T^3] \quad \text{(from –200 to 0°C)} \quad \textbf{(1)}$$

$$R(T) = R_0(1 + AT + BT^2) \quad \text{(from 0°C and 661°C)} \quad \textbf{(2)}$$

As an example, the coefficients for a Pt100 resistor (a platinum constructed, 100-Ω RTD) according to the IEC751 and international temperature scale (ITS-90) standards are given here:

$R_0 = 100\ \Omega$; $A = 3{,}908 \times 10^{-3}\ °C^{-1}$

$B = -5{,}775 \times 10^{-7}\ °C^{-2}$

$C = -4{,}183 \times 10^{-12}\ °C^{-4}$.

Another coefficient, α, is a linear parameter defined as the normalized slope between 0 and 100 °C.

Advantages and limitations

RTDs have good accuracy, precision and longterm stability. Concerns about maintenance, cost and accuracy are the primary drivers in the shift to the use of RTDs from thermocouples. Thermocouples will have a lower initial cost, when compared to RTDs, but the value of the accuracy and stability offered by RTDs often exceeds the initial cost savings of installing a thermocouple. With thin-film RTDs, as opposed to wire-wound designs, the cost difference is smaller.

Thermocouples may still have to be used in situations where process temperatures exceed the limit of an RTD (650°C), or when a very fast response is needed. However, there are some fast-response RTD designs available that may also negate the use of thermocouples in the latter case. Thin-film RTDs are typically limited to temperatures of 260°C, while wire-wound elements can withstand temperatures up to 650°C. Also, due to the construction of the sensing element, thin-film RTDs do not perform as well in environments where high levels of vibration or severe mechanical shock occur. ■

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Bio-Butanediol Production from Glucose

By Intratec Solutions

Butanediol (BDO) refers to all butylene glycol isomers. The most common isomer — 1,4-butanediol — is a versatile intermediate chemical used in the manufacture of plastics, elastic fibers and polyurethanes. Commercial processes for producing bio-based BDO from sugars have emerged in recent years as alternatives to petroleum-derived BDO. This one-page process description outlines the production of BDO by the fermentation of glucose.

The process

The following paragraphs describe a process for bio-butanediol production from glucose (Figure 1) similar to the process described in patents issued to Genomatica Inc. (San Diego, Calif.; www.genomatica.com).

Medium preparation. The preparation of the culture media involves dilution tanks, pumps and sterilizers. The culture media used in the batch and fed-batch phases of pre-fermentation and fermentation are prepared by mixing process water, glucose and nutrients.

Fermentation. In the fermentation area, the applied recombinant microorganism is initially propagated in inoculum fermenters, then sent to seed fermenters to promote growth until the concentration required for the main fermentation is reached.

The main fermentation is performed in fed-batch mode under aerobic process conditions in agitated, jacketed fermenters. At the batch phase, the microbe seed is fed into the fermenters, previously filled with the fermentation batch medium. After glucose exhaustion, the batch phase ends, and the fed-batch phase begins.

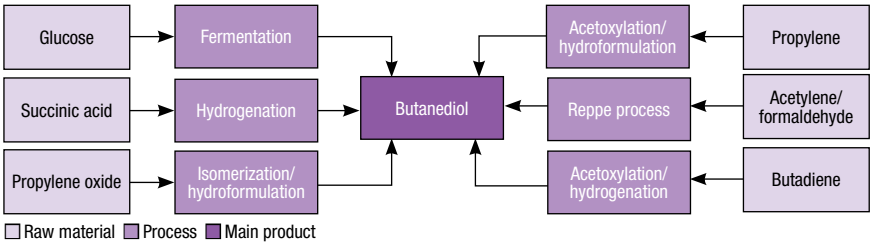

FIGURE 2. Several production pathways are available for producing butanediol

During the fed-batch phase, glucose and nutrients are continuously supplied. When the desired butanediol concentration is achieved, the feeding is suspended and the fermentation gradually decreases until being interrupted. The fermentation temperature is controlled by circulating cooling water through the fermenter jackets. The pH is controlled by ammonia injection.

Separation. The fermentation broth is passed through a centrifuge that separates cells and other insoluble particles. The separated biomass is discharged, while the broth is directed to ultrafiltration, used to remove soluble organic impurities, residual cell bodies and suspended solids.

The permeate is carbon-treated using a nanofiltration step for salts separation, color removal and desalination. The retained salts and sugars are discarded, while the permeate liquid is sent to an ion exchange separation step for removal of inorganic cations and anions.

The butanediol solution from ion exchange is then concentrated by water evaporation. The evaporation is carried out in falling-film evaporators and a forced-circulation evaporative crystallizer. The concentrated solution obtained is directed to a purification stage. The overhead stream (mostly water) is condensed and recycled to the fermentation stage.

Purification. The concentrated solution is fed to a distillation column for light-end impurities separation, and the light ends are discarded. The bottoms product, comprising the BDO, is fed to another column, in which high-purity 99.5 wt.% BDO is recovered as the overhead stream.

Production pathways

Petroleum-derived BDO is mainly produced by continuous hydrogenation of the 2-butyne-1,4-diol over modified nickel catalysts. Figure 2 presents different BDO production pathways.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce BDO was about $2,100 per ton in 2014. The analysis is based on a plant in the U.S. with capacity to produce 75,000 metric tons per year of BDO. This column is based on "Bio-Butanediol Production from Glucose," a report published by Intratec. It can be found at: www.intratec.us/analysis/butanediol-production-cost. ■

Edited by Scott Jenkins

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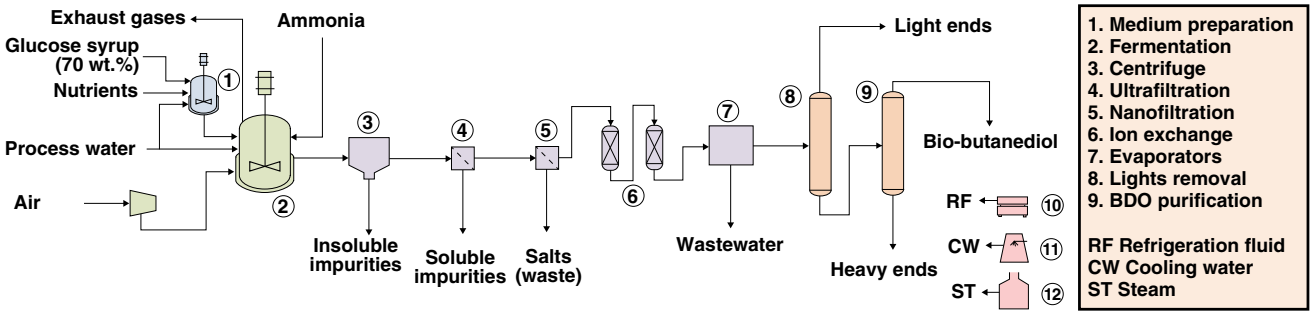


FIGURE 1. The process shown here describes the production of butanediol via the fermentation of glucose

Best Practices in Capital Equipment Commissioning

Ensuring that real-world commissioning tests are properly executed can benefit both equipment end users and suppliers

Peter Kalish
OBG

IN BRIEF

Every capital equipment project comes to a point when operations teams expect payback to begin on the investment. How soon those benefits are realized is driven by the effectiveness of the handoff from the equipment supplier. Those projects that rely only on acceptance tests to signal production readiness tend to experience delays, higher costs and lost output. The most effective handoffs involve comprehensive commissioning. The difference between acceptance and commissioning is key.

FIGURE 1. Effective commissioning should incorporate in-depth real-world tests that evaluate process variabilities and interdependencies

Acceptance tests are designed to show that a solution meets a set of objective contractual requirements. These are tangible deliverables, are not subject to interpretation, and are demonstrated according to tightly controlled conditions. Commissioning, however, is a real-world test using actual production resources (materials, staff and infrastructure) that are subject to uncertainties within an industrial ecosystem. Effective commissioning tests must incorporate elements of variability and interdependency, which are difficult to replicate in simpler acceptance tests (Figure 1).

Consider a project where a new piece of capital equipment works perfectly throughout both factory and site acceptance tests. The equipment is handed off to production operations and final payment is approved. Then, production starts and one of the first batches of material has properties that are slightly out of tolerance. The material-handling system fails to effectively convey the material, forcing a shutdown as the engineering team and supplier perform troubleshooting. Weeks of production output are lost. And both the equipment purchaser and supplier suffer unplanned labor and material costs.

This is a common example — where fully compliant equipment fails to deliver acceptable results because of interdependent activity or variability in other parts of the operation. In fact, there are many sources of troublesome interdependency, including the following:

- Inadequate training of maintenance technicians can result in faulty repairs that cause damage to sensitive components
- Utilities infrastructure may fail to provide sufficient stability in line voltage, generating controller faults that cause downtime
- Material shortages can force equipment into a turndown condition outside of its

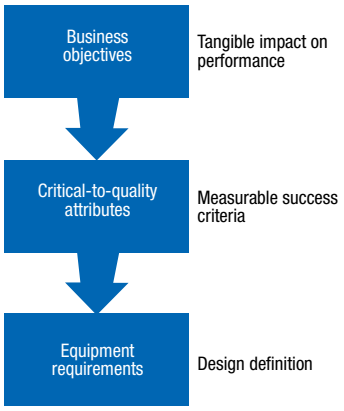


FIGURE 2. Primary business objectives are at the top of the flowdown hierarchy, helping to define which attributes are considered critical-to-quality (CTQ) during commissioning planning

design range, causing quality defects and reduction in throughput

While these issues can prevent new equipment from delivering expected benefits, they are also outside the typical scope of the supplier. The inability for the equipment to meet business objectives turns the capital investment into a liability (even if only temporarily), damaging the supplier's reputation and creating a lose-lose situation for buyer and seller.

For new capital equipment to reliably meet business objectives, there must be a commissioning period that accounts for both technical capabilities and operational interdependency. Effective commissioning involves five best practices that must be considered:

1. Define flowdown requirements
2. Create a comprehensive specification
3. Design for commissioning
4. De-risk the project
5. Extend the supplier's engagement

This article details each of these best practices and provides guidance in implementing them during capital project execution.

Define flowdown requirements

Planning for commissioning begins as specification requirements are being defined. Business objectives defined as part of the investment rationale are the basis for critical-to-quality (CTQ) attributes and, ultimately, detailed requirements (Figure 2). This flowdown of requirements provides a roadmap for commissioning. In commissioning tests, the goal must be to show that equipment requirements, CTQ attributes and business objectives are met.

For example, a business that seeks to increase its product throughput capacity might flowdown the business objective to equipment requirements as indicated in Figure 3. On the left side of the diagram, in the green shading, are typical technical requirements that would be in an equipment specification. To the right, in tan shading, are operational interdependencies that can have a significant impact on whether the throughput increase will ever be realized.

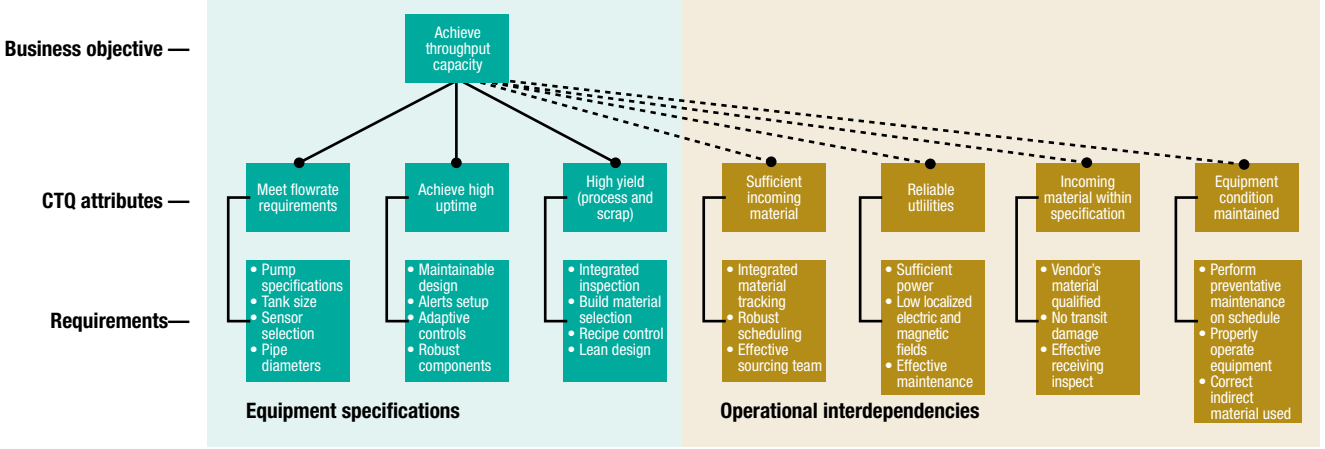
Note that CTQ attributes are measurable, even those related to operational interdependencies. It is vital that the commissioning plan identifies how CTQ attributes will be measured and the acceptable range of values. For instance, flowrate requirements may be measured at a particular point in the system and may apply only at a specific turndown ratio. "Reliable utilities" might be a measurement of voltage variation or cooling water flow and temperature.

Suppliers need to be made aware of operational interdependencies early in the design process. And commissioning tests must be set up in a way that assures interdependencies are addressed. This way, the buyer understands the standard to which adjacent factors must be managed to achieve the business objective. Even more important is the potential for substantive changes in equipment design that might mitigate some of the impact caused by interdependencies.

Create a comprehensive specification

Achieving a rapid and complete startup of new capital equipment demands clarity on what constitutes success. The success criteria are outlined in a specification that, too often, focuses heavily on technical details, and not enough on business performance. The only true measure of success is performance to the investment rationale established by business leadership.

FIGURE 3. This diagram shows an example of the relationship between business objectives, critical-to-quality (CTQ) attributes and equipment requirements



A strong specification will incorporate both technical and performance criteria. Technical criteria include process flows, applicable standards, interfaces, system components, controls strategy and documentation requirements. To address performance requirements, specifications should also include several additional elements, which are detailed in the following sections.

CTQ attributes. These are measurable attributes that establish how the system is to meet business objectives. For instance, if the business objective is to achieve higher throughput, one of the CTQ attributes would be a certain percentage of uptime. Detailed technical requirements might address some aspects of this requirement, but by alerting the supplier that the entire system must achieve a defined uptime, better design decisions can be made.

Commissioning tests. The specification should be clear on which real-world tests will occur after acceptance tests. The request for quote can ask for vendor support of commissioning tests to be a separate time and materials quote, but it is important for the supplier to understand how success will be defined during commissioning. This section might address staffing of the equipment, range of materials to be tested, deliberate stress tests (for example, voltage fluctuation or pressurized air shutoff) or recipe variants.

Roles and responsibilities. The specification needs to define roles and responsibilities that demand a partner-

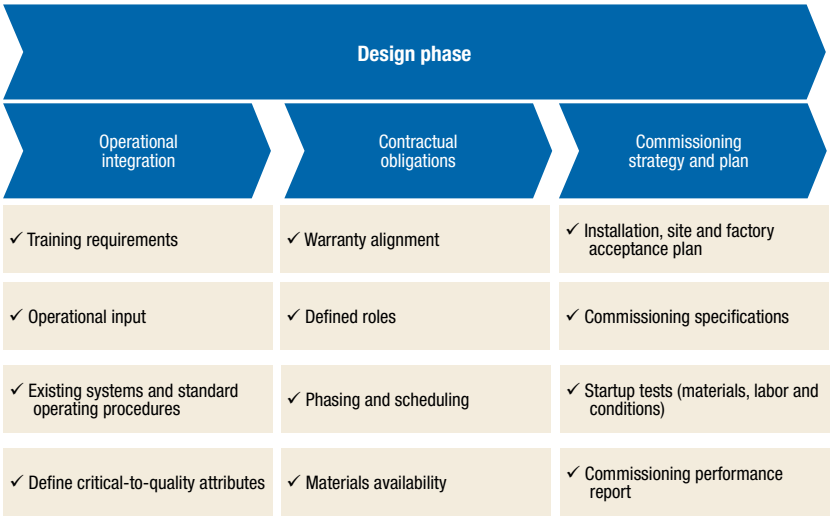


FIGURE 4. Incorporating commissioning plans into the design phase can help to minimize scheduling issues

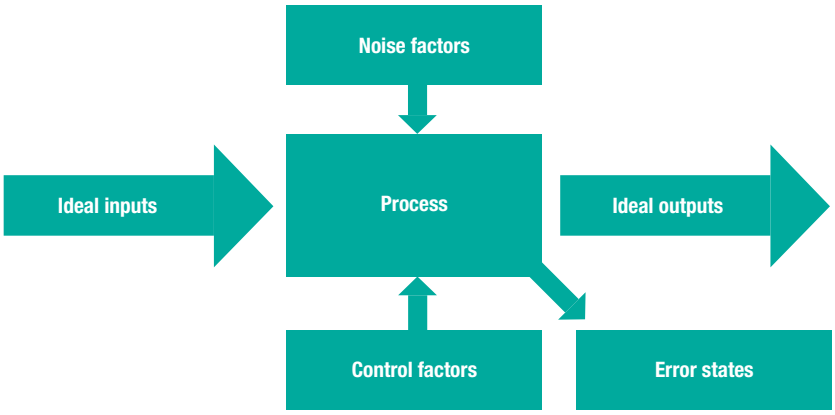


FIGURE 5. A p-diagram, such as the simplified example shown here, helps engineers in considering potential real-world factors that may disrupt a process

ship approach between the supplier, technology team and operations staff. For instance, shop floor operators can provide invaluable information about the legacy processes. Maintenance technicians can explain their methods for executing preventive maintenance and any issues associated with plant infrastructure, and production schedulers can provide information on the reliability of material flows and expected shift patterns. This is a strategy whereby suppliers understand potential sources of variation and account for them throughout the design, build, install and commissioning tasks.

High-risk proof-of-concept tests. Many new equipment designs incorporate a technical "leap of faith." This could be reliance on a brand-new sensor or processing a larger batch than ever before. To de-risk the project, proof-of-concept tests should be required as part of the specification. Besides providing confidence that a high-risk attribute is largely reduced, these tests make supplier design teams smarter about the process their equipment will serve.

Documentation. Most specifications will have standard requirements for documentation, which may include operating manuals, maintenance instructions and drawings. However, operating manuals do not typically go far enough in explaining how the process will run. They tend to have an equipment-centric view. There should be a documentation requirement that speaks to the operator and the maintenance technician. If a particular parameter setting is critical to achieve consistent quality, it should be documented. If there is a safer sequence for disassembling a part of the system, the manuals should provide that guidance. Very few manuals have this level of detail and shop-floor personnel usually express frustration at the lack of completeness. Of course, suppliers are not necessarily process experts, so operations teams and suppliers must work together to achieve a higher standard of documentation.

Design for commissioning

The handoffs within the equipment purchasing process — from business leadership to engineering and then to a sourcing team — can obscure the business objective that drove the initial investment decision. As a result, suppliers typically do not fully understand the reason why many requirements exist. This disconnect can result in lower-performing equipment.

A more effective way for equipment purchasers to engage with suppliers is to incorporate commissioning requirements into the design phase. This does not relieve the purchaser from being clear on technical capabilities. Instead, it expands the interactions between the buyer and seller to include performance-related needs and establishes a design team that will typically work together throughout the project.

As shown in Figure 4, operational integration is a set of activities undertaken by the design team to embed real-world effects into design concepts. It contemplates the environment into which equipment will be installed and ensures that interdependencies are considered by designers. This is where CTQ attributes are clarified and made part of the commissioning performance tests.

Commissioning should be made part of the contractual framework, with obligations of the supplier and purchaser clearly established. By capturing these obligations during the design phase of the project, the likelihood of commissioning success increases. Many of these contractual obligations cannot be outlined prior to the start of design, so they may be incorporated into a separate contract. Also, since many of the commissioning tasks have a higher level of uncertainty, they may lend themselves to a time and materials contract structure — as opposed to the fixed-price contract typically used for equipment purchases.

Finally, the commissioning strategy and plan must be detailed during the design phase. Factory and site acceptance can be viewed as the baseline set of commissioning activities, where equipment capabilities are demonstrated. But additional commissioning

specifications must be outlined, capturing the operational interdependencies discussed above. Startup test details would be part of the commissioning plan, to include resources and timing. Materials needed in commissioning tests may take some time to prepare or source. By making these plans during the design phase, schedule impact can be minimized.

De-risk the project

When new capital equipment does not meet business objectives, it is usually due to component failures or process disruptions. When designing robust equipment, suppliers should evaluate these sources of variance and identify methods for mitigating their impact. When commissioning equipment, these same variations should be part of testing. Two design tools, borrowed from product engineering, that can help equipment project teams, are the parameter diagram (p-diagram) and the failure modes and effects analysis (FMEA).

The p-diagram was developed by Joseph Juran to take inputs from a system and relate those inputs to desired outputs of a design. Used in many signal-processing applications, the p-diagram establishes a set of ideal inputs and ideal outputs, then guides the engineer to consider factors that can disrupt the ideal process (Figure 5). Ideal inputs, process description and ideal outputs are defined in the best case, where everything works without disruption. To keep the process running as close to this ideal as possible, control factors are applied. An example would be valve position in a flow application.

Noise factors are sources of variance likely to impact a process. Typically, these factors will involve the environment, infrastructure stability, human factors, equipment condition, materials variations, degradation effects or interactions with other equipment. Developing a p-diagram forces design teams to consider how noise is to be addressed. One option is to modify the design to convert a noise factor into a control factor.

By identifying error states, the p-diagram allows designers to consider what happens to the system when things go

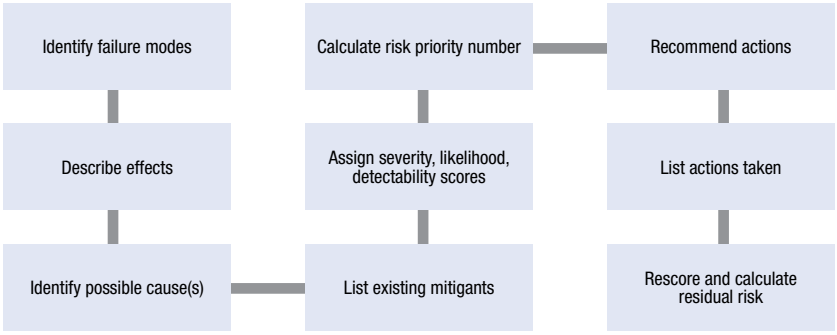


FIGURE 6. Employing failure modes and effects analysis (FMEA) tools during capital equipment design can help suppliers and operations teams to create a common vision for handling potential failures

wrong. Commissioning plans will typically test each type of error listed on the p-diagram to show that the system achieves a desired error state.

Several specific noise factors identified in the p-diagram that should be evaluated during commissioning are described in the following paragraphs.

Human impact. Operators that run commissioning tests should be those who will be responsible for production after equipment handoff is complete. They should run equipment without guidance from engineering or the supplier. After full handoff to the operations team, operators will make mistakes. Commissioning should confirm that equipment is robust enough to handle these mistakes. And, as commissioning tests are executed, gaps in training will become clear, allowing the operations team to engage the supplier on a more effective training process.

Material variabilities. Identical materials sourced from different suppliers can behave differently when processed. Individual suppliers can have process disruptions that inject new material properties not captured in procurement specifications. These can impact equipment performance. Upstream processes inside the factory may have their own variations that are passed downstream. During commissioning, testing should include a range of material characteristics and properties. Tests should be run on known out-of-spec materials to determine how the new equipment will respond.

Infrastructure disruption. Any infrastructure that plays a critical role in equipment operation (such as power, cooling water, vacuum, air pressure, heating, ventilation, air conditioning and so on) should be considered in commissioning tests. For instance, disruptions can occur in some processes if the room temperature rises on an abnormally hot day. Systems must be able to survive power failures and return to a known state upon power restoration. These types of issues must be resolved if they prevent equipment from meeting business objectives.

Volume swings. Fluctuations in factory material flow can impose a turndown condition on a piece of equipment that is at or beyond the design turndown ratio. Forcing an out-of-spec turndown condition during commissioning allows assessment of impact on quality and reliability.

Degradation effects. Most maintenance documentation will identify consumable components within systems. As these components degrade, the equipment must continue operating. Well-designed commissioning tests can evaluate how the system may operate with clogged filters or leaky seals. These are examples of conditions that the system will eventually encounter. Controls must be able to handle these situations without damage to equipment or hazard to personnel.

The failure modes and effects analysis (FMEA) is a decision-support tool developed by the U.S. military in the late 1940s to improve the reliability of its defense systems. In the FMEA, project teams identify likely ways in which the system might fail, the impact of those failures, why they might occur, how likely it is to happen and whether there is warning beforehand (Figure 6). Failure modes are given a score for each characteristic and then prioritized. Failures that have the biggest impact, happen most frequently and occur without warning will have the highest priority, expressed as the product of three numerical scores: severity, likelihood and detectability.

The FMEA is not just an assessment tool. It is a means for identifying design issues and driving toward solutions that will reduce the risk to an acceptable level. By incorporating the FMEA into capital equipment design, suppliers can deliver more reliable solutions. However, it is critical that the supplier and operations team be involved in developing the FMEA to create a common vision of how the system is likely to perform and identify acceptable methods for dealing with failures.

Having performed an FMEA, the supplier should demonstrate that design mitigations were effective within the commissioning period. Specific failure modes should be stress-tested with passing results. When an installed solution is shown to survive the highest-

priority failure modes, the risk of having outages that negatively impact business objectives is greatly reduced.

Extend supplier engagement

On fixed-price contracts, suppliers have a natural incentive to complete their work, close out the project and receive final payment — that payment usually represents their profit. Furthermore, equipment buyers have their own incentive to begin showing financial gain from significant funds invested. For these reasons, equipment is usually handed off to operations before it is fully ready to interact with all of the surrounding and interdependent systems.

If a deliberate commissioning effort is not planned and executed, a form of "casual commissioning" still occurs. It just happens in a slower and more costly manner. When operations teams encounter issues in the course of daily activity, instead of deliberate commissioning tests, skilled resources must be reallocated from other priorities. In extreme cases, suppliers are pulled back into the plant for support — possibly triggering a warranty dispute. Many suppliers will assume this cost in the name of customer-centricity, reducing their profit, even when it is not an issue within their control. This casual commissioning process can be costlier than the initial investment in equipment and usually is a lose-lose scenario.

A better way to achieve full performance of new capital equipment is to add a separate extended service engagement to the end of the purchase contract. This extension should include services by the supplier to support real-world commissioning. The contract would be customized to the type and complexity of equipment, and it would typically have multiple phases, described as follows:

- The first phase would be intensive and onsite engagement of supplier technical resources to resolve any equipment issues encountered under deliberate testing of noise factors
- The second phase would be reduced onsite presence of a supplier project manager to monitor performance and work with operational teams to resolve issues associated with interdependencies (for example, maintenance procedures, accurate work instructions or

scheduling anomalies). If new technical issues arise, the project manager can call in resources from the technical team at the supplier

- The final phase might be a longer-term service contract that allows for "pay-as-you-go" supplier engineering assistance if less common performance issues occur

The definition of extended support scope would occur in the design phase, as described above. Performance targets would be agreed upon by both parties. As there are many factors involved in meeting performance targets, the supplier cannot be expected to provide a guarantee. However, a sliding payment scale can be incorporated to provide incentive for the supplier to help drive the system to target performance.

Final thoughts

Improved commissioning processes demand a renewed alignment between purchaser and supplier objectives. The frustration purchasers have when their new capital equipment does not work as expected is usually mirrored within the supplier's business. Most suppliers care that their solutions deliver investment returns for their customers. They also feel frustration when circumstances beyond their control degrade performance. By following commissioning best practices, capital equipment investments can more reliably achieve their investment objectives, creating a win-win scenario for the purchaser and supplier. ■

Edited by Mary Page Bailey

Author

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Part 2

Commissioning and Startup: Increase Certainty Through Advanced Planning

Taking commissioning and startup into consideration during the early design phase can result in more predictable project schedules and more robust equipment designs

Anna Farokhi and Charlie Lyda
Fluor

IN BRIEF

DESIGN PHASE

EQUIPMENT PRESERVATION PLANS

MODULE-YARD EXECUTION PLANS

SITE-SPECIFIC EXECUTION PLANS

Historically, new capital projects and facility upgrades in the chemical process industries (CPI) were designed with a primary focus on operations. As the CPI have worked to reduce the total installed cost (TIC) of projects, many engineering, procurement and construction (EPC) firms have begun to incorporate modular design and fabrication methodologies into their project-execution strategy. The design teams spend considerable time finalizing the site plot plans. The objectives here are to compress the overall plot footprint and reduce piping and electrical system quantities, while still considering the construction execution sequence (Figure 1).

FIGURE 1. Many large capital projects in the CPI put great focus on decreasing overall costs and compressing plot footprints, but they must do so while still considering the proper construction execution sequence

As module-design techniques continue to mature, piping-system lengths are reduced, the density of the operating equipment is often compressed, electrical system quantities are minimized and the total cost of construction is reduced. Recent data suggest that with modular designs, piping and electrical systems quantities can be reduced by 25 to 30% when compared to traditionally designed facilities.

While the cost of design, materials, construction labor and logistics can be easily developed and compared against historical data to illustrate the TIC benefit of new techniques, the potential benefits to the commissioning and startup of the facility are not easily understood or quantified.

In addition to modular designs, projects continue to transition from the typical execution model — consisting of mechanical completion, commissioning and startup — to a parallel-activity model where power, utility and process systems are commissioned and placed into service while construction continues in other facility areas and systems.

Especially in this type of project-execution environment, early involvement of the commissioning and startup team members is critical. Involvement of the team during module design reviews and the development of equipment preservation plans, module-yard execution plans, site commissioning and startup execution plans and performance testing plans leads to safer execution, a reduced project TIC and optimized project schedule durations. This article describes several areas where early in-

FIGURE 2. Utility systems are typically the first to become operational during a large facility startup

volvement and advanced planning from the commissioning and startup team can improve a project's certainty with regard to costs and scheduling.

Design phase

Information from the system piping and instrumentation diagrams (P&IDs) and electrical system one-line drawings are marked on the issued-for-design (IFD) drawings to define startup system boundaries and serve as the basis for the construction and commissioning teams' planning efforts. The design databases — including equipment lists, instrument lists, piping isometric lists, cable databases and so on — are populated with the startup system identifiers attached to each component and help to drive system- and commissioning-test completion. The component tags in these databases, along with agreed-upon attributes (including the startup system identifier), are uploaded into the completions software and updated as the design progresses. These data sets are very useful in the early construction planning phase and are required during the final phases of a project.

Early involvement of the commissioning and turnover team during the development of the inspection and test plans (ITPs) included in the site quality manual reduces the cost of tracking and locating the documentation required for systems completion and commissioning. Specific system-critical documents should be loaded and connected, as required, against the applicable components in the completions software. Early agreement on these documents by several parties — the quality, commissioning and turnover teams, as well as the startup team and client — facilitate this work during the project's systems completion, turnover and handover phases.

The modular design techniques that drive down construction costs are reviewed from the commissioning and startup perspective to ensure that pre-commissioning, commissioning and startup activities are supported and included in the modular design considerations.

To guide this process, mark up a series of plot plans illustrating the sequence in which the systems or units will become energized or operational. Each drawing (one per project month is recommended) reflects all energized systems and areas from the previous month, with the addition of systems coming online in the current month. Additional plot-plan drawings are marked up until the entire facility is shown as operational. To read more on plot plan drawings, please see Plot Plan Design: Process Requirements, *Chem. Eng.*, Jan. 2015, pp. 52–57.

These marked-up plot-plan drawings provide the project team with a high-level overview of the path from construction to final operation. Through these marked-up drawings, engineering teams can visualize better layout options; construction teams can validate construction sequences and execution plans; health, safety and environmental (HSE) teams can better prepare the required safety programs as areas become operational; and commissioning teams can better prepare for the detailed system-isolation design reviews.

Utility systems, such as power, instrument air, service water, cooling water, steam and so on, are typically the first systems to be made operational and often span across multiple modules and process-unit boundaries (Figure 2). A detailed review of these systems and the construction sequence may lead to the identification of additional isolation points. Incorporating additional components into the base design that are not required for normal operations but support commissioning and startup minimizes cost and schedule impacts later in the project lifecycle.

A similar review of the process systems is conducted to ensure that provided isolations support the construction execution sequence as the systems

are commissioned and placed into initial operational service.

A detailed review of piping-system cleaning needs is conducted in parallel with the isolation review noted above. This review identifies additional components that may be required to support the piping-system cleaning that will be required prior to initial operation. These cleaning activities typically include air blows, water flushing, hydrolazing (ultra high-pressure hydroblasting), steam blows and pipeline and system dry-out activities.

This review focuses on access points for cleaning services, availability of rollout spools, bypass provisions to flush around critical components and the entry and exhaust points of the activities. During this review, identify all permanent plant equipment that may require removal prior to the cleaning activities, such as valves, valve trims, orifice plates or flow nozzles. As this review progresses, identify all materials that may be required for reinstatement and develop the material requisition information required. This review forms the basis for the detailed cleaning plans that are developed during the site commissioning and startup planning phase prior to field mobilization.

Equipment preservation plans

The need to develop detailed equipment-preservation plans early in the project cannot be overstated. These plans ensure that equipment is properly stored and maintained prior to its delivery and final installation on site. The comprehensive equipment-preservation plan is often a combination of EPC and client quality program requirements, coupled with the equipment suppliers' recommendations. As supplier information is received, the documents should be reviewed with a focus on preservation and any requirements recorded in the completions software. It is advisable to include any required forms in the vendor purchase orders that outline and record preservation activities. This requirement saves countless hours and potential omissions when reviewing and searching the vendor manuals for requirements. If modular execution strategies are employed, the equipment preservation program should be in place to support the equipment arrival at the module yard facility and continue through shipment to the site (Figure 3). Execution plans are developed to ensure a comprehensive program is conducted through initial operation with validity of data recording maintained throughout the program.

Module-yard execution plans

The pre-commissioning and commissioning activities conducted at the module yard are clearly defined to ensure alignment with all parties and validate that expected results (and cost reductions) are realized.

Photo of Shell Quest carbon capture and storage project

FIGURE 3. Equipment preservation programs should be in place to support equipment arrival at the module-yard facility through shipment to site

To minimize site rework, documentation requirements must be clearly identified in advance and incorporated appropriately into the project completions software.

Consideration for the electrical and control-system components to be distributed on process modules should be evaluated. Many pre-commissioning and commissioning activities, such as loop checks, motor run-ins, power system energization and so on, can be conducted in the module yards if supported in the process module design.

The team develops a detailed pipe-system cleaning strategy for the module yard and incorporates that strategy into the project's overall system-cleaning specialty requirements (Figure 4). Items to consider during plan development include module size, shipping durations and cleanliness preservation during shipment, as well as cleaning activities that will be required onsite prior to equipment going online, including component removal and re-installation to support the required cleaning processes.

Evaluate the module yard infrastructure prior to finalizing commissioning plans. Consider power availability (voltage, capacity and frequency), cleaning media capacity, pumping capacities, water retention facilities, waste management and other applicable areas. The final plan includes any requirements for maintaining cleanliness during transit, such as purges, end caps, routine monitoring and so on.

Site-specific execution plans

The site-specific commissioning and startup execution plans are an extension of the planning efforts performed to date. The system isolation requirements have been identified, the flush connection points have been validated, the equipment removal list to support flushing has been developed, module yard pre-commissioning and commissioning plans and documentation are developed and the equipment-preservation management plan is fully functional. Building on the previous efforts, the team develops system-specific procedures defining the activities required to bring the plant up to its ready-for-startup (RFSU) status.

Each process piping system of the facility has specific procedures outlining many areas, including the following:

- The cleaning required to be performed at the site
- Cleanliness acceptance criteria
- Component removal checklists
- Parts required listing
- Component restoration checklist
- Equipment isolation checklists
- Any post-cleaning drying and preservation requirements

A set of "cleaning" P&IDs are developed for inclusion into this system cleaning package.

During piping-system flushing and steam-blow activities, tremendous amounts of water are required. A temporary water-management plan is developed as part of the commissioning and startup planning process. This plan includes several important items, including the following:

- Limitations on makeup water availability
- Limitations on wastewater discharge
- System designs that consume water as part of the operational process
- Limitations in onsite storage

The plan provides the system drawings required for temporary piping systems and equipment, a strategy document summarizing water movement around the site and a final waste-disposal plan. The team considers the use of permanent plant sumps and retention basins in the temporary water-management strategy.

As steam-blow plans are developed, carefully consider the routing of any temporary pipe, the location of the ex-

haust points and the source of the steam generation. Should the steam source be provided by the existing operating facility, a steam-flow demand plan is extremely helpful in coordinating the operating facility interfaces. Because multi-unit facilities rely on the process units to generate the steam required for facility operation and power generation, the startup source (for instance, an auxiliary boiler or heat-recovery steam generator) may not have the capacity required to meet the downstream requirements for cleanliness criteria. As cleaning plans are finalized, the teams consider temporary sources for the steam supply, the required fuel-supply connections, steam system connections and temporary exhaust points.

Building on the activities performed in the module yards, detailed procedures are developed to finalize the pre-commissioning activities for the electrical systems, instrumentation and controls systems and equipment lube-oil flushing activities.

System- and unit-specific startup procedures are developed based on the manufacturer or licensor's instructions, process system descriptions and major-equipment supplier manuals. Assembling this information prior to mobilization ensures that a comprehensive startup program is in place and that the appropriate reviews are performed. The procedures include sections outlining the interface requirements to other units within the facility, special drying and refractory-curing processes, temporary feedstock requirements (if any), initial valve alignment tables, initial operating setpoints and a summary of equipment operating alarms.

Similar to the process-system commissioning procedures, electrical-system energization plans are developed to ensure the proper pre-energization testing is performed, all safety precautions are in place and the correct energization sequence is followed.

The electrical and process system startup procedures are developed to align with the project-specific lockout/tagout (LOTO) procedures, electrical arc-flash safety procedures, system boundary tagging and blinding procedures and established HSE practices and procedures.

All of these individual pieces come together to provide great benefits in terms of more-effective plans and designs. The opportunity to influence a project's safety, productivity, cost and schedule is at its greatest during the design phase. The commissioning and startup teams' early involvement enables the development of a comprehensive set of testing activities that span the project lifecycle, commencing at the module yards and completing at the site in support of a successful facility startup. Conducting early design reviews with a commissioning and startup focus reduces total costs significantly and yields a more predictable outcome in the field. ■

Edited by Mary Page Bailey

Photo of Shell Quest carbon capture and storage project

FIGURE 4. A detailed pipe-system cleaning strategy must be developed for the module yard

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Part 1

Wireless Monitoring for Pressure Relief Systems

New diagnostic devices can identify when pressure incidents happen, while keeping an eye on the condition of pressure-relief valves and rupture disks

Marcio Donnangelo
Emerson Automation Solutions

IN BRIEF

Any kind of pressurized system, from the hot-water heater in a residence to a massive chemical reactor, will have some sort of pressure relief mechanism. It's there to let internal pressure escape before it overcomes the mechanical strength of the equipment. This concept is as old as the earliest steam boilers, and its function is to protect people and equipment.

Early pressure-relief-valve (PRV) designs were simply openings held shut by weights. Modern versions are more sophisticated, using springs that can be fine-tuned to open at very specific pressure setpoints and pilot-operated valves that bring a higher level of stability to avoid chattering. PRVs come in a variety of sizes and need to be matched with the overall size of the system and its ability to generate pressure. If pressure can't be released faster than it can be generated, the valve is too small. If the valve is too large, it could become unstable during a release.

A relief system for a process unit generally involves more than one PRV. System design guidelines are covered in the ASME Boiler and Pressure Vessel Code (BPVC), Section VIII. It provides detailed explanations of the variables involved in creating an overall system based on the maximum allowable working pressure for the equipment and a range of other variables. Naturally, design of a relief system should be left to experts, given the importance it has in the overall safety strategy for a plant or facility.

Pressure relief options

Conventional PRVs (Figure 1) are useful in situations where overpressure incidents are common or even routine, since they can reseal themselves when the pressure recedes. If working correctly, no maintenance action is necessary to resume normal operation. However, as we will soon discuss, the functionality

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FIGURE 1. Pressure relief valves are available from a variety of sources in a vast range of sizes, all providing the same basic functionality

of a given valve or a system overall can be difficult to evaluate without sending operators out to manually inspect each valve.

PRVs are mechanical and do not need any electronic components to function. Consequently, they don't have any built-in mechanism capable of reporting their condition or activity. If operators want to know what is happening with a given system, they typically depend on watching normal process pressure measurements for indication of operation near the PRV's setpoint.

PRVs are not the only relief mechanism. A rupture disk can provide a less expensive, but more maintenance-intensive solution. As

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FIGURE 2. An acoustic monitoring device listens to an adjacent device. It can be programmed to identify characteristic sounds and report its evaluation via a *Wireless*HART network

the name implies, in the event of an incident, the disk splits open and releases the pressure contained in the system. The action is drastic, and the process will certainly have to be shut down, because once a disk is ruptured, it cannot reseal itself. Rupture disks are typically made of relatively thin metal, usually stamped or scored to allow them to split at a specific pressure. In some cases, they have been known to develop pinhole leaks, allowing release of the process fluids.

Like PRVs, rupture disks have no built-in mechanism for reporting their condition or functionality. Usually, operators recognize an incident by a significant loss of system pressure. Some users place a mechanically activated switch on the back side of the disk to indicate rupture.

Pressure relief systems might release the contents to atmosphere if the products involved are environmentally benign, but more often, individual relief points feed into a system to collect liquids, while sending gases to a scrubber, recovery system or flare. Any product released will typically be unrecoverable or recovered for a less noble application, such as feeding energy to boilers and furnaces. This loss adds to the cost of an incident, along with possible environmental consequences and fines. Since the header connection covers the outlet of either type of device, it may not be clear to operators trying to troubleshoot the situation which valve or disk has opened if the answer is not identifiable from normal process operating information.

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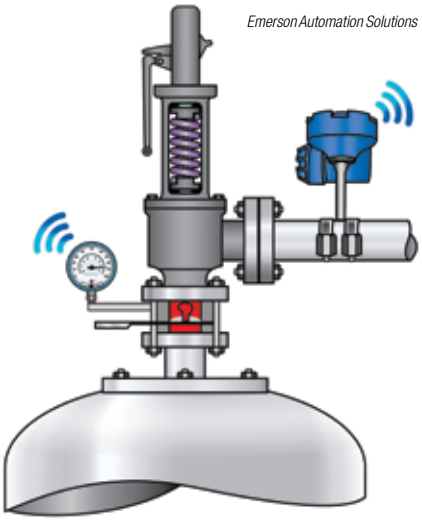

FIGURE 3. If pressure develops between the disk and the PRV, it will not blow out at the design pressure. A pressure gage can warn if pressure goes above atmospheric

Monitoring relief devices

Monitoring the condition and activity of PRVs and rupture disks should be a part of normal plant operation, but as previously mentioned, there are no mechanisms within the devices

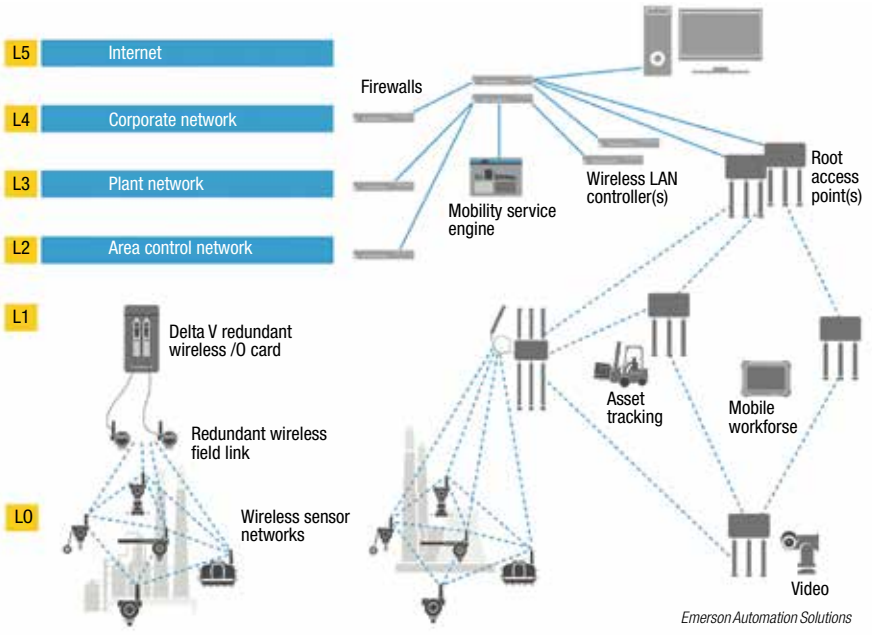

FIGURE 4. A *Wireless*HART network is self-organizing and can support a wide variety of process instruments and monitoring devices

capable of sending information to an automation system. Creating a monitoring device borrows from traditional maintenance techniques: listening.

"Old-timer" maintenance technicians can diagnose a device by sticking a screwdriver against it and putting an ear to the handle. More sophisticated individuals might carry a stethoscope-type device or a hand-held instrument, both of which are designed to capture ultrasonic sounds. These need to be applied directly to the subject device by an operator, so they aren't suitable for permanent, continuous monitoring.

Acoustic monitoring devices (Figure 2) are now available that are designed for mounting directly to pipes adjacent to valves, PRVs, steam traps and other common fluid handling equipment. They capture sounds transmitted directly through the metal at high frequencies, above human hearing limits, so ambient noise is not a concern.

Fluids flowing through the devices mentioned make various sounds, particularly when some part of the mechanism is affected. For the purposes of this discussion, we'll concentrate on how acoustic monitoring devices can identify characteristic sounds of PRVs.

A slow leak

A PRV retains its seal by having a spring hold the stem against the seat. A fully-closed valve makes no noise because nothing is flowing through it. When the system pressure exceeds the setpoint, it opens, releasing the contents of the system — either liquid, gas or both. This creates turbulence, generating noise that an acoustic monitor can hear and report to the automation system.

If the system pressure is sufficiently relieved or the process is adjusted to reduce it, the valve should close again. If everything is working correctly, it will seal and the noise will cease. Data from the acoustic monitor can report the time the discharge began and ended, while giving some indication of how serious the discharge was based on the amplitude of the sound.

The problem many plants face is getting the valve to reseal. Since overpressure incidents are often related to process upsets, particulate matter in vessels and pipes can be stirred up and blown out with the contents. Some particles can lodge in the valve seat and keep it from closing entirely, leaving it in a perpetually leaking state, which operators call "simmering." This leakage may not be enough to cause problems with the process, but it does release product that must be handled by the unit's pollution control systems.

A knowledgeable operator might be able to infer which valve is simmering from process data, but often, it can take some time for personnel to realize there is a problem at all, much less where it might be happening in a complex system with many PRVs. An acoustic monitor will hear the simmering, even if it is very slow. Operators checking the monitors can tell immediately if a given PRV has fully reseated itself after an incident. Maintenance then decides when to address the issue based on the cost or danger of the product and the volumes involved.

Chattering can be the cause and result of valve damage. If a valve is too large for the application or goes through a long but slow period of overpressure, it may open and close many times, beating the sealing surfaces together, scratching the seat and valve or bending the stem. A displacement of hundredths of a millimeter can create a gap capable of releasing pressure, but is also detectable by an acoustic monitor.

Combination installations

PRVs are sophisticatedly designed and carefully calibrated, so they can be very expensive — especially large sizes and units made in special corrosion-resistant alloys. By comparison, rupture disks are much cheaper. Some users install a rupture disk and a PRV in series on the same vessel. The disk faces the process while the PRV backs it up, so the disk has a slightly lower pressure limit than the PRV. This provides a best-of-both-worlds arrangement:

- After an incident, the rupture disk will be blown, but the PRV can reseal itself, allowing the process to continue operating until the disk can be scheduled for replacement.
- The rupture disk is the only part exposed to the process, so if special alloys are necessary, only the disk needs to be purchased in the expensive material. The PRV should have sufficient corrosion resistance so it can be exposed to the process for an extended period, at least long enough to allow the process to be shut down and the disk replaced.
- This combination system requires effective monitoring for the reasons delineated above, and because it is required under the ASME standard.

Avoiding a serious problem

The biggest drawback to this type of combination installation is the potential for failure during an incident. Here's how: there must be an interstitial space between the rupture disk and PRV since they cannot be up against each other. This is a sealed space because anything coming through a blown disk needs to pressurize the PRV so it will open and allow the contents to release to the collection system.

The interstitial space needs to be at atmospheric pressure because rupture disks are normally rated for release to atmosphere. If the space between the two devices has greater than atmospheric pressure, the trapped pressure will press against the back of the disk, and it will not rupture until system pressure has reached the burst point plus the interstitial space pressure.

Rupture disks do occasionally develop microscopic pin-hole leaks, typically caused by extended operation near burst pressure. If this happens, gas or liquid can leak through (Figure 3), equalizing pressure on both sides of the rupture disk, and ultimately reaching full system process pressure. Under such conditions, the rupture disk may no longer serve its desired function as the weakest link in the containment chain. Consequently, ASME BPVC Section VIII UG-127 specifies that any installation using a combination rupture disk and PRV system must have an indicator to monitor the pressure of the interstitial space to detect a disk rupture or leakage.

This function can be performed by something as simple as a mechanical gage or even a try cock provided an operator passes by on rounds at appropriate intervals. The other extreme is using an electronic pressure transmitter sending its data to the unit's distributed control system (DCS) or safety-instrumented system (SIS) via a wired connection. This is arguably best, but also the most expensive solution.

There is a middle-ground approach that accomplishes both, but without the high cost. There are electronic pressure gages capable of providing a local display while also sending data via a *Wireless*HART network. Operators can read the device while on rounds, but it can also provide an alarm to the automation or safety systems if desired. These can be added without installing new cabling or adding I/O slots to the process automation system.

Monitoring via wireless networks

Acoustic monitors and electronic pressure gages can use the same *Wireless*HART network as other wireless field devices (Figure 4). This allows pressure-relief system monitors to interface with a larger automation system, while also sending data to the maintenance team. With continuous monitoring, technicians can tell in an instant if a pressure release is underway, if a valve has not fully resealed itself, or if a rupture disk is starting to fail.

New application software is a ready-to-use solution able to characterize a release event by interpreting information from an acoustic transmitter, eliminating graphic interpretation by operators and false positives. It also requires electronic acknowledgement of when and what action was taken after an event occurred. This is critical information for environmental compliance but also for a PRV maintenance program.

With prompt action, the overall effectiveness of the unit's safety system can be assured while avoiding product loss and potential environmental consequences. Many equipment condition monitoring devices are now available that can help determine how well many types of assets are functioning. This information can help optimize maintenance efforts and avoid costly unplanned shutdowns. ■

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How to Troubleshoot and Maintain Pressure Regulators

Following a five-step process enables better outcomes for fluid system control

Jon Kestner
Swagelok Company

IN BRIEF

Most often, operators and technicians will interact with components like ball valves or needle valves when adjusting a system's operation. However, just as important to the effectiveness of a system are the pressure regulators that work to deliver steady pressure, so these common valves can perform their function. Pressure regulators are complex fluid system components that require careful thought during system design, installation and operation to realize safe, trouble-free performance. A regulator's main purpose is to maintain steady pressure in a fluid system application. However, a regulator's ability to reliably perform that function can become compromised over time and may require investigation to determine if the regulator itself is the problem or if another system issue is to blame.

Swagelok

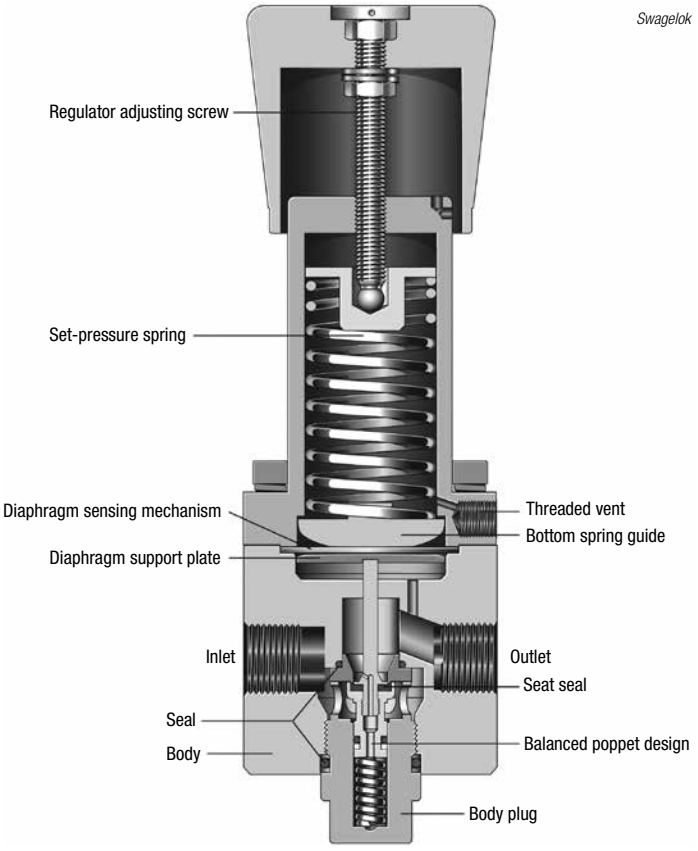


FIGURE 1. The components of a pressure-reducing regulator include: the set-pressure spring, which is the controlling mechanism; diaphragm, which is the sensing mechanism; seat; poppet, which is the sealing mechanism; body; body plug; inlet and outlet ports; threaded vent; and more

Issues such as the following are most commonly related to the regulator's seat, diaphragm and poppet:

- Pressure leakage across the seat when closed
- Loss of pressure control
- Fluid leakage to atmosphere

These issues do not necessarily mean the regulator needs to be replaced. The regulator can likely instead be maintained to prolong its life and reduce its total cost of ownership. In fact, maintenance is to be expected, as the Compressed Gas Association (CGA) notes that "regulators do not have infinite service life" in its pamphlet E-15-2017, "Guideline for Periodic Service Program for Industrial Gas Regulators, 3rd Edition."

To properly troubleshoot a regulator's performance, technicians can follow a five-step process that begins with testing the regulator, followed by inspection and a decision on whether to maintain, overhaul or replace it — based on assessments from the first two steps. We'll review this process, along with exploring common issues associated with regulators, including causes and solutions, to help chemical plants, petroleum refineries and others in the chemical process industries (CPI) realize better outcomes from their fluid systems.

Step 1: Testing regulators

Testing a regulator is highly recommended — if not required — following regulator in-

TABLE 1. COMMON REGULATOR SYMPTOMS, CAUSES AND REMEDIES

Symptom	Cause	Remedy
The outlet pressure creeps up without adjusting the spring	A damaged poppet and/or seat	Replace the poppet and/or seat
Leakage around the body plug	A damaged O-ring	Replace the O-ring
Leakage between the body and the spring housing or through the spring housing weep hole	A damaged diaphragm or O-ring	Replace the diaphragm or O-ring
	Insufficient torque on the cap screws	Tighten the cap screws per the manufacturer's guidelines
Controlled pressure drops off sharply even when the flow is within the regulator's capabilities	The system filter element is clogged	Replace the system filter
No outlet pressure is seen when adjusting the handle clockwise	The diaphragm is distorted and is not contacting the poppet	Replace the diaphragm
The required outlet pressure cannot be reached	The inlet pressure to the regulator is not high enough	Ensure that the inlet pressure to the regulator is equal to or greater than the desired set pressure
The outlet pressure does not drop when the knob is adjusted counterclockwise	The regulator is non-venting	Open a shutoff valve in the outlet line to reduce the outlet pressure
The outlet pressure has changed without adjusting the handle	Changes to the inlet pressure may result in changes to the outlet pressure	Maintain a constant inlet pressure to the regulator
	Changes to the flow may result in changes to the outlet pressure	Maintain a constant flow through the regulator

stallation and maintenance to ensure accurate, as well as safe, operation. System operators should also test a regulator if they notice leaks, unexpected pressure increases or decreases, or any of the issues noted in the "Regulator Troubleshooting Tips" sidebar (p. 56) and Table 1. Testing should be part of a facility's preventive maintenance program, with regulators placed on inspection intervals based on their service environment and industry recommendations.

To verify a regulator's operation, maintenance technicians will typically perform two primary tests — a seat test and a shell test — to ensure the regulator isn't leaking within the system or to atmosphere.

Seat leak test. To perform seat leak testing, a technician will conduct both a low-pressure and a high-pressure test to ensure the seat seals with the regulator poppet under both conditions and doesn't allow pressure and system fluid to escape to the outlet side. Such leakage is known as creep, and can result from damage to the seat or from debris stuck between the regulator's poppet (also called its main valve or control element) and seat. (See Figure 1 for a diagram of regulator components.) Since the shut-off force on a regulator seat is related to the inlet pressure, conducting both a low- and high-pressure test is important to ensure that the seat can operate well across a wide range of pressures. Very often, the low-pressure test is a more difficult test to pass due to the smaller closing force generated by the lower inlet pressure, as opposed to a high-pressure test, where the larger closing force may deform the seat around seat damage or debris, creating a seal even when the seat may be compromised.

For either the low- or high-pressure test, the technician should first ensure sufficient supply pressure is available to the regulator to perform the tests and then screw the handle fully counterclockwise, allowing the poppet to fully close against the seat. For the low-pressure seat leak test, the technician should slowly raise the inlet pressure to approximately 14.5 psig (1 bar) on the regulator and allow the pressure to stabilize before checking for leaks. Once the inlet pressure is stabilized, the technician will monitor the regulator's outlet pressure, watching for any increase that would indicate a seat leak.

For the high-pressure seat leak test, this procedure is repeated using the highest inlet pressure applicable for the regulator and system. After monitoring the regulator's outlet pressure during this high-pressure test, the technician will know if the seat is installed properly, creating a seal even at the highest application pressure.

Shell leak test. To conduct a shell leak test, a technician will increase the regulator's inlet pressure to approximately 29 psig (2 bars) and then close the downstream shutoff valve. Next, the technician will adjust the regulator handle to increase the outlet pressure to approximately 14.5 psig (1 bar) to ensure the regulator's internal components are energized. Using a liquid leak detector, the technician will check for bubbles at the interface of the spring housing and body, the interface of the body plug and body (if equipped), and the spring housing weep hole (if equipped). Finally, the technician will repeat these procedures using the highest inlet and outlet pressures applicable for the regulator and system.

Other tests. While these two primary tests will help identify regulator leaks, maintenance technicians may need to dig deeper to diagnose other regulator anomalies. The following tests are not common, but may be necessary at times.

Overshoot test. If the regulator is slow to respond to pressure changes, a technician may perform an overshoot test. This test helps diagnose conditions such as a damaged O-ring that impedes the poppet's natural action, a frozen regulator, or a weak poppet spring, all of which can affect the regulator's ability to maintain a consistent setpoint pressure and potentially cause operators to make incorrect adjustments. To perform this test, the technician will set the regulator to a desired setpoint, shut off the upstream flow, and then vent everything downstream, so no pressure remains inside the regulator. Because the regulator is set, its poppet will remain open. The tech-

REGULATOR TROUBLESHOOTING TIPS

When troubleshooting a regulator, maintenance technicians can address a variety of symptoms by replacing components, checking and adjusting settings, and toggling isolation valves. In some cases, however, they will need to replace the regulator. In others, they may not have to maintain the regulator at all and will instead need to address some other issue within the fluid system.

Among the numerous issues technicians may find when testing and inspecting a regulator, the following five issues are the most common, from most to least frequent.

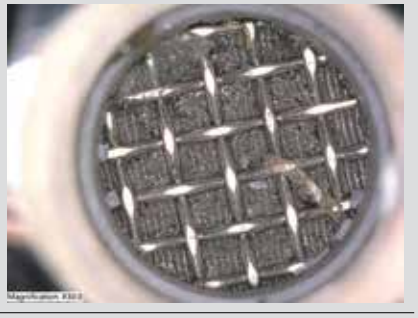
Seat creep. A particle stuck in the seat or a damaged seat may allow pressure and flow to escape — or creep — across the regulator's seat when it should otherwise be closed, resulting in an unwanted downstream pressure rise. To address a regulator that displays creep, clean the seat if possible or replace it using a maintenance kit. To help prevent seat creep, consider adding filtration upstream to block particles from reaching the internal regulator components.

Diaphragm distortion. Excessive downstream pressure can cause a diaphragm to distort, particularly around its rim where the spring cap and body hold it in place. The distorted diaphragm may no longer contact the poppet and therefore not be able to actuate the poppet, resulting in no flow moving through the regulator. In this case, the technician will need to replace the diaphragm. To reduce the likelihood of overpressure damaging the diaphragm, facilities can add a pressure relief valve downstream.

Diaphragm crack. Chemical attack or cycle fatigue from pulsations may cause a diaphragm to crack and/or form a hole, which will compromise its sensing – and therefore pressure control – capabilities. A cracked diaphragm will require replacement. Adding a pulsation dampener or using a piston-style regulator may help to minimize this issue within systems where heavy pulsation could be expected.

Shell leak. Leakage from ports on a regulator's shell is typically caused by chemical attack as corrosive materials compromise the integrity of sealing materials. Replacing the damaged seal may be enough to correct the issue, provided the technician uses the appropriate seal compound for the system media.

Flow restriction. A restriction in downstream flow could be caused by a clogged filter. The simple fix is to either replace or clean the filter. Adding additional upstream filtration can also help mitigate this problem. However, if the issue is persistent, the maintenance technician may want to increase the filter replacement frequency. ❑



nician will then open the upstream isolation valve to reinitiate flow. With the poppet already open, the regulator poppet will need to adjust its position to regulate pressure at the new flow. Due to the short time the poppet needs to adjust its position, a downstream pressure spike above the regulator's set point is possible. This spike is the overshoot value, which should ideally be no more than 5–10% above the regulator's setpoint.

Lock-up test. If a large, abrupt change in pressure is observed when starting or stopping flow through a regulator, there may be a need to perform a lock-up test to help determine how much pressure the system loses when starting flow and how much the pressure increases when stopping flow. Some lock-up is acceptable, but it should be no more than 10% of the regulator's control range, as high lock-up values can impede a regulator's ability to maintain consistent outlet pressure. Lock-up, sometimes referred to as seat load drop, occurs when operating a regulator near

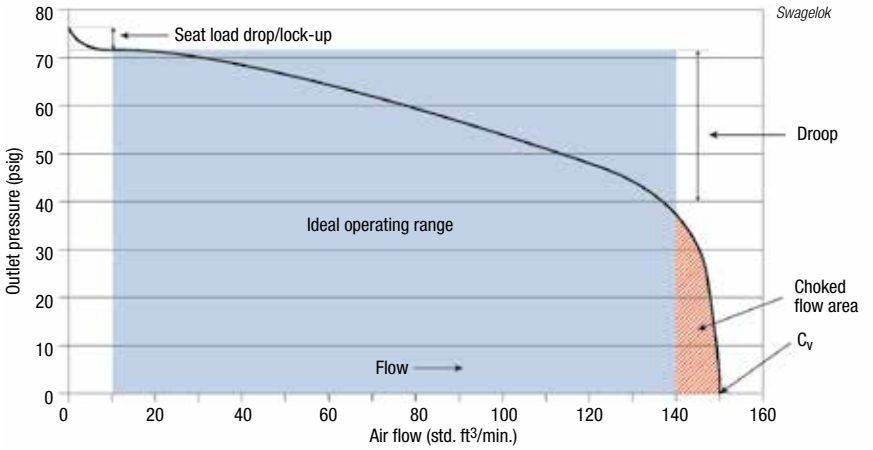


FIGURE 2. This typical flow curve for a pressure-reducing regulator demonstrates how seat load drop, or lock-up, affects the regulator's ability to maintain control near its startup and shutoff point. The diagram also shows the ideal operating area for the regulator, its flow coefficient (*Cv*), and the phenomena of outlet pressure droop and choked flow, which can both occur as flow increases

its startup or shutoff point. When starting flow upstream, the downstream pressure will drop drastically until the regulator catches up to the newly applied force (see the seat load drop/lock-up zone noted at the far left of the regulator curve in Figure 2). The opposite scenario occurs when stopping downstream flow, as the regulator may suddenly snap shut as it approaches a no-flow state. In either case, the regulator may chatter or pulsate as it fluctuates between flow and no-flow conditions.

If a regulator passes some or all these tests, the technician's work may be completed until the next planned maintenance cycle. However, if leaks are uncovered during seat and shell testing, or the results of overshoot or lock-up tests are not satisfactory, the technician will need to investigate further.

Step 2: Inspecting regulators

Issues discovered during testing may warrant opening the regulator and examining its internal components for signs of debris, deformation, cracks, heavy chemical attack, or other damage. The three most common regulator components that require maintenance, in order of upkeep frequency, include the following:

Seat. The seat serves a sealing function that allows the regulator to contain pressure and prevents fluid from leaking to the opposite side of the regulator when flow is shut off. Common causes of leakage across the seat include debris stuck on the seat and damage. Either issue may prevent the regulator's poppet from fully engaging in the seat and forming a complete seal. Sometimes a technician only needs to clear debris, clean the seat, and retest the regulator to fix the issue. However, damaged seats may require replacing.

Diaphragm. The diaphragm is the regulator's sensing element and operates by flexing up and down to allow the regulator's poppet to rise and fall within the seat to control outlet pressure. Debris may impact the diaphragm and, if found in the sensing chamber, should be cleared. However, it typically won't affect the regulator's sealing capabilities. More likely, a technician may find damage to the diaphragm from chemical seal degradation due to incompatibility with system fluids and/or evidence of stress from fatigue or overpressure (particularly when using a metal diaphragm regulator). These conditions will affect the diaphragm's ability to adequately sense and respond to pressure fluctuations and may warrant replacing the diaphragm.

Poppet. In combination with the seat, the poppet both controls the outlet pressure while a system is flowing and completes the sealing process to prevent pressure from escaping to the regulator's outlet port when flow is shut off. In a pressure-reducing regulator, the

poppet is typically spring-loaded and held vertically in the inlet channel, with the tip in constant contact with the diaphragm. When closed, the poppet fits against a precision-machined seat and should create a high-tolerance seal. Any damage to the poppet, such as a deep scratch, may compromise that seal and necessitate a replacement. A poppet may also become stuck or hindered within its typical range of motion, in which case it should also be replaced, potentially along with the poppet spring and any associated O-rings.

Step 3: Maintaining regulators

Following inspection, a technician will need to determine whether it's possible to replace a few select components to restore regulator functionality, or if it's necessary to perform a major overhaul or even replace the regulator.

Per the CGA's guidelines about regulators not having infinite service life, facilities should plan to maintain regulators periodically. Therefore, technicians should expect to replace components such as a regulator's seat, diaphragm, poppet, springs or other components, depending on the demands of the application.

The CGA also notes that "materials used in regulators, particularly elastomeric or rubber materials, will deteriorate over time," showing signs of "hardening, stress cracking and other physical property degradation." For this reason, the association recommends replacing not just damaged components, but also any seals, backup O-rings, or other parts directly associated with the operation of that component. For example, when replacing a regulator's seat, a technician should also replace the seat retainer O-ring, since the two components have a tolerance fit. Even if the O-ring appears to be in very good shape, it may have hidden wear and could be responsible for future seat leakage. Plus, since the technician already has the regulator open, it is likely less expensive to replace the O-ring at that time as opposed to waiting for a failure and incurring the additional expense of future maintenance downtime. Supporting the CGA's recommendation, many manufacturers sell kits featuring the part being replaced as well as any associated components.

Step 4: Overhauling regulators

When replacing a few internal regulator components does not correct an issue, maintenance technicians may need to change all the regulator's internal wear components. This overhaul could mean replacing the regulator's range and poppet springs, spring plates, diaphragm, seat, poppet, seals and more — essentially anything that moves inside the regulator or is associated with a movement function. The few components that typically don't need to be replaced include the regulator's handle, body, spring cap and hardware.

Facilities should overhaul a regulator on a reactive basis when testing and inspection procedures indicate the need. The CGA also recommends overhauling a regulator at five-year intervals, but the time between service will vary based on application demands. To keep track of maintenance cycles, the CGA advises facilities to add tags to regulators that indicate their most recent maintenance service. Facilities should also add these data to their internal maintenance records to enable easier tracking and scheduling.

Step 5: Replacing regulators

Following testing and inspection, a technician may determine maintaining or overhauling a regulator is simply not feasible, in which case, the technician will install a new one. This practical decision may be based on the condition of the regulator, such as damaged threads that can't be retapped or heavy chemical damage to components that can't be replaced. It is also often driven by economics. Facilities will most commonly overhaul process-style regulators featuring ports that are 1-in. diameter or larger. Such regulators are typically expensive, so it is often more cost effective to replace all the internal components, compared to purchasing a new regulator. However, for smaller, instrumentation-sized regulators, it may be more feasible to simply replace the regulator and not spend the additional time replacing internal components.

Troubleshooting outcomes

When selecting a regulator for a fluid system, CPI plant operators must consider the total system design. That means addressing and understanding the function, material compatibility, ratings, installation, operation and maintenance of a regulator before making a choice. After the regulator is installed, their work is not complete. Maintenance personnel need to monitor the regulator and periodically test its performance to verify proper operation. These activities may reveal issues that require further inspection that may potentially result in some simple maintenance, minor component replacements, a complete overhaul, or even a full replacement. By following the five-step process noted above and learning the common symptoms and solutions associated with regulator performance, facilities can realize longer life cycles from these important components — and therefore reduce their overall operating costs. ■

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Combustible Dust Fires and Explosions: Recent Data and Lessons Learned

A review of recent data from the Combustible Dust Incident Database provides insights into dust-related process safety

Chris Cloney
DustEx Research Ltd.

Fires and explosions in facilities that handle combustible dust remain an ongoing focus of process safety efforts across many areas of the chemical process industries (CPI). But how many dust-related safety incidents occur each year? This question is a major driver behind the formation of the Combustible Dust Incident Database (CDID; Halifax, N.S., Canada; www.dustsafetyscience.com). Created in 2016, the CDID features a twice-yearly report on fires and explosions having to do with combustible dusts. The CDID is an online portal with the purpose of reporting, tracking and generating lessons learned from fire and explosion incidents around the world. The database is meant as a tool for technical decision makers to anticipate upcoming difficulties and process safety trends in their industries, and to give the powder-handing community a platform to measure and manage combustible dust hazards.

The information collected and tabulated on combustible-dust incidents in the CDID is now helping to determine trends and tendencies in the materials, industries and equipment involved with these hazards.

This article outlines the findings from the incident reporting completed to date. Comparisons are made between the CDID information and historical combustible-dust explosion data within the U.S. Also, an overview of the personal and financial loss resulting from these types of incidents is provided.

The incident research discussed here is based on publicly available information, including news stories and other resources accessible by Internet search engines, as well as social media sharing, government sources and industry repositories. It is important to note that articles may contain incomplete or, in some cases, incorrect information. Furthermore, dust fires and explosions often go unreported, and the totals reflected here may vastly underestimate the total magnitude of the problem. This is especially true internationally, where the news coverage is sometimes limited.

TABLE 1. COMPARISON OF AVERAGE YEARLY INCIDENTS IN THE CSB DATA AND CDID

Source	Date range	Total years	Average explosions per year	Average injuries per year	Average fatalities per year
U.S. CSB	1980–2005	26	11	28	5
U.S. CSB	2001–2005	5	19	43	9
CDID	2016	1	31	22	3
CDID	2017	1	28	39	6
CDID	2018*	1	24	10	1
CDID	2016–2018	3	28	24	4

*2018 totals are projected from the mid-year incident report

Incident reporting

The first incident report [*1*] was released in 2016 and covered combustible dust explosions within North America. In 2016, 31 explosions were reported in the U.S. and two were reported in Canada. These incidents caused a reported total of 22 injuries and three fatalities in 2016.

In 2017 mid-year and year-end incident reports were released [*2*]. The year-end report covered both combustible dust fires and explosions around the world. In North America, 132 fires, 32 explosions, 61 injuries, and six fatalities were recorded. Four of the explosions were reported in Canada, while the other 28 were in the U.S. Internationally, 37 fires, 36 explosions, 102 injuries and seven fatalities were recorded.

The 2018 mid-year incident report [*3*] was released in August 2018. In addition to global fire and explosion incidents, the Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov) citations, upcoming events, and new technology and products were also featured. In the first six months of 2018, 75 fires, 14 explosions, nine injuries and one fatality were reported in North America. One of these explosions occurred in Canada and 13 within the U.S. Internationally, 14 fires, 12 explosions, 31 injuries, and eight fatalities were recorded.

The reports can be downloaded by navigating to the following link: www.dustsafetyscience.com/solids-processing-2018.

Comparison to historical data

The most comprehensive analysis of combustible dust incidents in the U.S. is the Combustible Dust Hazard Study [*4*], published by the U.S. Chemical Safety Board (CSB; www.csb.gov). In this report, the CSB reviewed combustible-dust flash fires and explosions over a 26-year period between 1980 and 2005. Comparing the average number of explosions, injuries and fatalities to those from the CDID illustrates how the loss from these incidents may be evolving over time (Table 1).

The CSB report shows an increasing trend in the number of combustible-dust incidents, injuries and fatalities, with the numbers almost doubling during the 20-year period from 1980 to 2001. The CSB cautions in their report that this increase may be due to limitations in previous reporting, including that the earlier incidents were under-reported.

The more recent CDID data show a steady continuation in the number of recorded dust-related explosions per year. The total increased by another 50% in the 10 years since the CSB report was published. However, the incident reports also suggest that the overall number of injuries and fatalities may be flattening or decreasing compared to the number of incidents. This tentatively suggests that an emphasis on combustible dust awareness, prevention and protection practices over the last decade may be reducing the average severity of any given explosion. It is again important to note that under-reporting in previous data may influence this conclusion. Furthermore, although the severity may be decreasing, neither dataset shows any single year with zero fatalities due to dust explosions in the U.S. since 1983.

Materials and industries

From the 2018 CDID incident reporting, wood processing, food processing and agricultural activities account for almost 60% of the dust-related fire and explosion incidents. Automotive manufacturing, metal working, power generation and mining contributed an additional 17%. The remaining 24% of incidents occurred in other industries, including pulp and paper, education, coatings, oil and gas, textiles and recycling.

Very frequently, materials involved in wood-product incidents were specified as sawdust or wood dust, and materials involved in food processing or agriculture were specified as grain dust. In cases were specific materials were named, pine chips, cellulose, corn, pecan, cocoa, flour, cereal, barley and spices were implicated in dust incidents. Although not broken out in the data, coal dust accounted for almost 7% of the total incidents. In cases involving metal dusts, aluminum, titanium, magnesium and iron were cited most often.

TABLE 2. EQUIPMENT CITED IN COMBUSTIBLE DUST INCIDENTS

Equipment	Fires	Explosions	Total
Dust collectors	25	3	28
Storage silos	8	9	17
Elevators/conveyors	7	5	12
Other storage	12	2	14
Other equipment	21	3	24
No details mentioned	16	4	20

Equipment and causes

Dust collectors tend to have the highest number of total incidents of all equipment involved in powder processing. However, the 2018 incident data suggest that these were more often fires than explosions. It is often difficult to distinguish between storage silos and elevators — these two terms are often used synonymously in much of the news reporting. Overall, storage silos, elevators and conveyors made up half of the explosion incidents, while accounting for a smaller proportion of the overall fires (Table 2). Other equipment includes mills, shakers, grinders, saws, dryers and cyclones.

Often, very little information is available that points to the initiating cause of combustible dust fire and explosion incidents. In specific cases highlighted in the reports, hot work, including welding and cutting metal, are listed as the initiating cause. Sometimes machine sparking and static electricity are indicated in news reports, although it is rare to have this substantiated by a formal technical review. Further development of the CDID will focus on working with local fire departments and government organizations to better communicate these causes when an official investigation has been performed.

Loss overview

It is instructive to organize the combustible-dust incident data in terms of different types of loss. This comparison provides some information about how fires and explosions impact injury totals, fatalities and facility damages individually, and allows trends from different materials involved in processing operations to be explored.

Global data from the first half of 2018 indicated that 89% of the fatali-

TABLE 3. DUST-RELATED INCIDENTS INVOLVING MORE THAT $1 MILLION IN DAMAGES				
Location	**Industry activity**	**Material**	**Type**	**Damages**
Springfield, N.H.	Planar mill	Wood dust	Fire	$5-10 million
Lawtey, Fla.	Sawmill	Pine dust	Fire	$1 million
Chesapeake, Va.	Biomass	Wood pellets	Fire	$1 million
Rogers, Tex.	Wood finishing	Wood dust	Explosion	$1 million
Cottage Grove, Ore.	Wood products	Sawdust	Fire	$10 million
Butler, Tenn.	Sawmill	Wood shavings	Fire	$1 million
Muskegon, Mich.	Die casting	Metallurgic dust	Fire	$15 million
Brookers, Alta.	Grain processing	Grain dust	Fire	$8–10 million
Elkview, B.C.	Coal mine	Coal dust	Explosion	$5–10 million
San Juan, N.M.	Power generation	Coal dust	Explosion	$15–20 million
Atlus, Okla.	Cottonseed plant	Cottonseed	Fire	$20 million

ties from dust incidents occurred due to explosions. With regard to injuries, 70% occurred from explosions, while 30% were the result of fires. The total breakdown of injuries and fatalities from fires and explosions is as follows: Explosions caused 28 injuries and eight fatalities, while fires caused 12 Injuries and one fatality.

This suggests that explosions tend to be more severe in terms of injuries and lives lost than facility fires. However, the trend for facility damages shows the reverse. Out of the eleven incidents with reported losses of $1 million and above, eight were from fires and three were from explosions. This highlights the importance of both fire and explosion prevention in facility safety measures.

In terms of materials involved, the number of fires, explosions, injuries and fatalities for the two most common categories are as follows: Wood products were involved in 33 fires, five explosions, 10 injuries and 0 fatalities, while food products were involved in 24 fires, 12 explosions, 14 injuries and eight fatalities.

Although both categories are responsible for a similar total number of incidents, fires appear to be more prevalent in wood processing facilities and explosions tend to be more common in food processing and agriculture. In cross-referencing these data with the equipment data provided earlier, these differences may be due to more frequent use of dust-collection systems in wood-dust-handling facilities and more frequent use of silos and conveyors for food production.

As a result of the higher number of explosions, food products have a larger number of high-severity incidents in terms of injuries and fatalities. In terms of facility damage, industry activities involving wood products resulted in more incidents that generated $1 million or more in losses. A summary of the high-damage incidents is shown in Table 3. Six of these incidents involved wood dust, sawdust, wood pellets and wood shavings. Five of these were fires and one was an explosion. This again demonstrates that both fire and explosion hazards need to be addressed in industries handling combustible dust.

Additional information on specific incidents can be found at www.dustsafetyscience.com. Ref. 5 contains an example of incident summaries.

Concluding remarks

After comparing data from the CDID, including findings from the 2018 mid-year incident report, with historical data from the CSB, the case can be made that combustible dust is a safety issue that deserves continued attention and focus. The data also suggest that efforts related to dust safety on the part of CPI companies, government agencies and other industry organizations may be having a positive effect: while the number of reported dust-explosion incidents is increasing over the past 40-year period, the number of injuries and fatalities per year since 2001 to 2005 may be leveling out, or even decreasing.

Other tentative conclusions that can be drawn from the data involve the materials and equipment types most likely to present a dust-safety hazard. The most frequently cited materials involved in combustible dust incidents include wood products and food products. While dust collectors had the overall largest number of incidents in the first half of 2018, they largely involved fires. Explosions occurred more frequently in storage silos, elevators and conveying equipment. The data available point to some gaps in information: often the initiating cause of fires and explosions involving combustible dusts is unavailable. This provides motivation for future efforts into improved procedures for collecting this information.

Information on the losses involving injuries, fatalities, and facility damages from dust-related incidents reinforces the need for countermeasures for both explosions and fires.

The CDID is actively collecting more information recording incidents as they occur. The ongoing analysis and richer trove of data will allow for more detailed explorations of fire and explosion incidents in industries outside of wood and food processing. ■

Edited by Scott Jenkins

Acknowledgements

The author would like to acknowledge that support for the CDID and incident reporting comes from member companies and report sponsors. A list of the 2018 report sponsors is provided here:

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Chris Cloney (PEng.) is the director and lead researcher at DustEx Research Ltd., (60 Bridgeview Drive, Halifax, N.S., Canada B3P 2M4 ; Phone: 902-452-3205; Email: chris@dustsafetyscience.com), a company with a worldwide focus on increasing awareness of combustible dust hazards and reducing personal and financial loss from fire and explosion incidents. Cloney spent five years working as an engineering consultant and software developer in the defense industries focusing on detonation, explosion, and blast research. Upon completing his Ph.D. thesis in the area of modeling coal dust and hybrid mixture deflagration, he moved into the world of online education focusing on sharing and connecting the combustible dust community.

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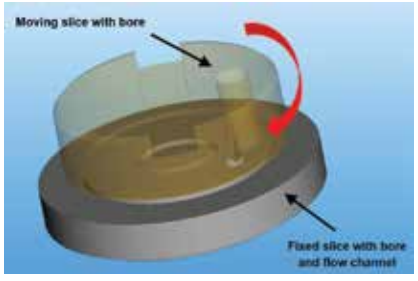
5. CDID incident summary for San Juan, NM, found https://dustsafetyscience.com/coal-fire-san-juan-new-mexico/.

More than 600 exhibitors from around the world will be showcasing their products at Valve World Expo 2018, the 11th International Valve Trade Fair & Conference (www.valveworldexpo.com), which is taking place at the Düsseldorf fairgrounds November 27–29. The exhibition, which is organized by Messe Düsseldorf GmbH (Germany; www.messe-duesseldorf.de), will encompass 194,000 ft^2 in three halls of the fairground.

The exhibits will be complemented by the Valve World Conference 2018 in Hall 4, with expert talks and workshops by international speakers. In addition, the Pump Summit will be held in Hall 5, featuring state-of-the-art pump technologies and the latest results from science and research. Acting as an interface between valve and fitting technologies, the Pump Summit will provide a valuable addition and create important synergies for visitors.

What follows is a small selection of products being exhibited.



ARCA Regler

A new approach for severe-duty microflow valve

A new, patent-pending approach for microflow control is based on a (rotary) sliding gate valve (photo), where two slices with lapped surfaces are installed in the valve, pressed together by a spring and the differential pressure. This enables zero-tolerance, without any limitation due to tolerances or thermal expansion. Each slice has one or more bores for the flow passage. Normally, the flow passage of such a sliding gate valve is only open when the bores overlap. Especially with small rated flow coefficient (that is, small bores), this results more or less in an on/off characteristic of the valve. In this new design, one of the slices is equipped with a tangential flow channel, which leads and expands into the bore of this slice. This enables a smooth control behavior with sufficient opening angle (more than 60 deg). The slices can be made of any material (even ceramics), which makes the trim resistant against each process fluid and pressure drop. Although the valve plug movement is quarter-turn, a standard globe-valve housing DN 15–25 (ANSI ½ to 1 in.) rated PN16–PN 250 (ANSI Class 150 – 1500) is used. This makes the design economic and allows changing from a standard valve to the new design, even at an existing valve, says the manufacturer. Hall 4, Stand A02 — *ARCA Regler GmbH, Tönisvorst, Germany*
www.arca-valve.com

Armaturenfabrik Franz Schneider

These twin ball valves provide double isolation

The Taurus Series Double Block & Bleed Valve (photo) provides a double-isolation function with a twin ball design and a bleed function by different bleed/vent valve designs. The block valves are available from 1- to 6-in. full bore (8-in. reduced bore). The standard flanged connections are offered by default according to ASME B16.5. The ball valves have an anti-blowout stem design and an anti-static design and are fire-safe tested and certified according to API 607 and ISO 10497. The Double Block & Bleed Piping Ball Valves are designed specifically for applications in the oil-and-gas industry. The following designs are available: two- or three-piece design; and floating-ball or trunnion-ball design. The Taurus Series is designed, developed and tested in Germany and certified by TÜV Süd. Hall 3, Stand C65 — *Armaturenfabrik Franz Schneider GmbH + Co. KG, Nordheim, Germany*
www.as-schneider.com

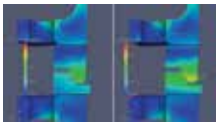
Garlock

An expansion-joint material designed for abrasion protection

Abra-Shield (photo) is a proprietary expansion-joint liner material designed for abrasion resistance and sustainability in demanding high-temperature operating conditions. As the newest addition to this company's family of abrasion-resistant expansion-joint materials, Abra-Shield joins Abra-Line and Natural Rubber to provide a variety of liners that cater to increased abrasion protection. Abra-Shield will be an option for use with a number of expansion-joint products that the company offers, including styles 204, 206, 7250, 8400 and 9394. These uniquely constructed joints also provide high levels of protection from stress, misalignment, vibration, noise, shock and corrosion. The specially formulated hydrogenated nitrile buta-

diene rubber used in Abra-Shield is said to perform significantly better than common abrasion-resistant solutions, with an operating temperature range up to 300°F. In abrasion resistance testing — which provides data to compare materials and predict the lifetime of a material or coating — Abra-Shield provided 50% higher abrasion resistance than standard EPDM (ethylene propylene diene monomer rubber), according to the company. Abra-Shield will be the recommended solution in abrasive applications (such as slurry, ash and brine) with sustained or spiked temperatures between 180 and 300°F. Hall 3, Stand D13 — *Garlock GmbH, Neuss, Germany*
www.garlock.com

In-house CAE service for reliable rupture disc operation


Rembe

This company is said to be the first rupture-disc manufacturer worldwide to offer relevant computer-aided engineering (CAE) services. For systems operators, it is therefore not necessary to involve an engineering firm or similar service providers that specialize in CAE. In conjunction with the company's products, its users receive a complete solution with real added value: CAE calculations for pressure relief guarantee the most reliable results, which are then used for customized production of the rupture discs. Originally, the CAE was reserved for internal purposes, but based on the positive feedback from many users, the company decided to intensify these services. Currently, the available user enquiries are particularly related to strength calculations and leak-tightness verifications. However, the company's CAE professionals are already working on many additional services. Hall 3, Stand E35 — *Rembe GmbH Safety + Control, Brilon, Germany*
www.rembe.de

Maximize space, reduce costs with new pressure relief valves


Emerson Automation Solutions

This company is helping LNG-marine transportation operators reduce their initial pressure-relief-valve investment at the shipyard, by up to 25%, and total cost of ownership with its new Anderson Greenwood 9300H low-pressure pilot-operated pressure relief valves (POPRVs; photo). The Anderson Greenwood 9300H patented design provides leak-free operation up to the set pressure with an additional 10.5% flow capacity over valves currently available on the market, says the manufacturer. The additional capacity reduces the required size of the valve, providing initial purchase savings, with additional savings on the associated piping, fittings and expansion elbows. Designed specifically for marine LNG tanks on ships, floating production or storage units, the valve allows ship owners and operators to efficiently fulfill their critical overpressure-protection requirements with smaller-sized valves and associated piping. Hall 3, Stand E19 — *Emerson Automation Solutions, Houston*
www.emerson.com

Gerald Ondrey

Inside

Safety and Efficiency for the Mobile Worker

Ecom provides mobile Industry 4.0 applications for hazardous areas

Networking people, plants, assets and systems is crucial for creating added value in the process industry. The interaction of explosion-proof mobile devices with professional applications is one of the key factors here. The **Pepperl+Fuchs** brand ecom provides an interlinked, compatible solution portfolio for the networked mobile worker in the Ex area.

Ecom mobile solutions are part of the company's interlocking, explosion-proof mobile worker concept, which includes smartphones, tablets, peripherals and software applications. Customers benefit from a consistent and future-proof solution and global service portfolio for the Ex area, which offers a complete range of new possibilities along the entire supply chain in an Industry 4.0 context. In combination with professional partner applications, the specialist for industrial communication and explosion protection offers a practical and safe mobile solution.

The interaction between intrinsically safe mobile devices and the right applications is crucial. Ecom's industrial tablet Tab-Ex 02 for use in Zone 1/21 is ideally suited for modern Industry 4.0-capable applications. It facilitates new, promising Industry 4.0 applications and makes work collaborative, efficient and safe – even in high-risk and isolated locations. The explosion-proof tablet combines highest performance parameters and resistance with Industry 4.0 applications. It is the perfect companion for a variety of tasks, e.g. inventory, material tracking, maintenance, supply chain and asset management. With the Tab-Ex 02, the user can record and retrieve data, parameters and information remotely at any time and in any location in real time.

With ecom's mobile solutions, companies not only increase productivity and improve their employees' safety, they also open up new fields of application. Smartphones, tablets and peripherals provide the technological basis for networked applications – the decisive factor for corporate success in the future.

www.pepperl-fuchs.com

BEUMER Group presents itself as single-source provider for packaging lines that work perfectly together

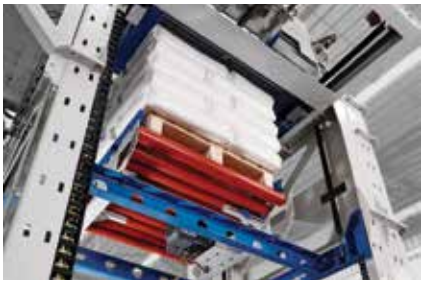
The chemistry is right

BEUMER Group offers the product family of the BEUMER fillpac FFS in various performance ranges.

BEUMER Group develops complete packaging lines from one source for (petro) chemical companies. This means that the customer can omit or minimise interfaces and only needs one point of contact. What is special is that the system supplier dimensions the performance of the single machines and components as well as the high-level control in an optimum way. Thus the customer receives a complete line with optimum throughput.

The form-fill-seal system BEUMER fillpac FFS forms a ready-made tubular PE film into a bag and fills it with the customer's product like PE, PP, PA or PS pellets. The pellets are then weighed before the filling process. For this, the BEUMER fillpac FFS is equipped with an electronic calibration-capable weighing unit. Then the system seals the bags with a weight of up to 25 kg. BEUMER Group offers the BEUMER fillpac FFS both for the high-capacity area of up to 2,600 bags per hour and for low throughputs up to 1,800 or 2,500 bags per hour. Depending on the customer requirements the suitable machine performance class can be selected from the extended product range.

After filling, the bags are stacked on pallets in stable and precise way. The BEUMER paletpac of the system supplier is perfectly suited to this. It is easily accessible for maintenance, can be operated intuitively and flexibly adapted to different packing patterns. For palletising cartons, boxes, canisters or trays, BEUMER Group offers the BEUMER robotpac. This space-saving, fully automatic articulated robot solves complex palletising and de-palletising challenges.



The BEUMER paletpac creates precise, stable, space-saving bag stacks.

The heart of the line is the high-capacity stretch film packaging system BEUMER stretch hood which covers the palletised goods with a high-stretchable stretch hood film. During transshipment and outside storage, the merchandise is protected reliably against environmental influences such as sunlight, dirt and humidity.

www.beumergroup.com

Digital view of the installed base

Endress+Hauser wants to help customers tap into this potential by using the data that is available in the field instruments. Although roughly 90 percent of the Endress+Hauser instruments installed around the world feature a fieldbus interface such as HART, Profibus, Foundation Fieldbus, Modbus, RS485, EtherNet/IP or Profinet, only three percent actually utilize this digital communications capability. Before added value can be generated from the data, it first has to be available in a consistent form. Many companies own field instruments from different generations and manufacturers, for which detailed information is sometimes lacking.

Endress+Hauser Analytics

The Endress+Hauser Analytics App helps capture the data from the entire installed base of field instruments and forwards it to a cloud-based online hub. After that, it is compared to the Endress+Hauser database, which is then updated with missing data. The database contains not only detailed information about Endress+Hauser's own field instruments, but in some cases also about competitor instruments, albeit with less detail. The application creates "digital twins" of the field instruments, which are visible by authorized persons from any type of end devices. Analytics reduces the time it takes to complete an inventory of the installed base to a fraction of what is required if the analysis is carried out by hand.

Predictive maintenance

Capturing and updating the data with Analytics opens up further opportunities to exploit the information. Therefor, Endress+Hauser is developing an application called Predict, which is currently being tested and optimized on a pilot basis with several customers. Predict permits customers to adapt the calibration and maintenance intervals to the actual needs of the operation. Inflexible intervals based on rule-of-thumb values are thus a thing of the past. As a result, system availability is increased and maintenance managers save time by reducing unnecessary service tasks.

Industrial Internet of Things applications are entering the area of process engineering. Endress+Hauser launched its first digital service for the automated analysis and management of an installed base: the Endress+Hauser Analytics App.

Endress+Hauser has been the first industrial company to receive the StarAudit certification by EuroCloud.

EuroCloud certification

Data security is thus a central aspect. But when it comes to data security, Endress+Hauser leaves nothing to chance. The Endress+Hauser IIoT Ecosystem was independently certified with four stars by the EuroCloud organization for highly sensitive data. Within the framework of the certification, all areas that are relevant for the collection of data in cloud-based applications were reviewed. The StarAudit certificate confirms that web-based services are based on specific security standards and have been correspondingly validated. This offers a traceable quality assessment of cloud services through a transparent and reliable certification process.

www.endress.com

Plants for Hydrogenation and other Gas-Liquid Reactions

MASS and HEAT TRANSFER limited reactions

The Challenge

The hydrogenation reaction is highly exothermic and very mass transfer resistant.

The Solution

The **BIAZZI**'s High Performance Reactor System (BHPR) is characterised by a high capability for heat removal, high rate of gas-liquid transfer, efficient agitation which provides the required gas-liquid transfer, shearing effects, high internal gas recirculation rate and liquid circulation in an optimal way.

The advantages

- High productivity
- High quality of the products
- Highest Safety standards
- Excellent batch to batch reproducibility of results
- Full performance guarantees
- Optimised operational expenditures
- Reliable and guaranteed scaling-up in shortest time
- Lowest maintenance needed

The fields of application of the BHPR in the chemical/pharmaceutical Industry Mainly for Hydrogenation but also for Oxidation, Carbonylation, Amination, Phosphination and Dehydrogenation.

Scale-up

BIAZZI scales up laboratory hydrogenation results directly to any size of industrial plants up to 50 m3 and gives performance guarantees covering capacity, product yield & quality, and catalyst consumption. Based on the tests results the industrial plant is designed and built in the shortest time.

Modular system

BIAZZI offers from Key-Equipment with basic engineering up to SKID mounted units.

www.biazzi.com

SIL-capable actuators protect BASF plant

AUMA has supplied electric actuators meeting SIL 2/SIL 3 requirements to a BASF incineration plant.

AUMA electric actuators are TÜV-certified for safety requirements up to SIL 3

SIL-capable **AUMA** actuators meet the highest safety requirements as part of a safety system for flue gas scrubbers on a BASF incineration plant in Ludwigshafen, Germany. The actuators operate flue gas dampers that protect the GRP scrubbers against excessive temperatures in case of emergency.

To prevent damage to the scrubbing system BASF implemented a protection scheme that, as an overall system, meets the stringent SIL 3 requirements according to IEC 61508. The system includes three flue gas dampers fitted with AUMA electric actuators that are TÜV-certified for use in safety-related systems up to SIL 2/SIL 3 (SIL 3 for redundant system architecture).

The first flue gas damper is installed upstream of the flue gas scrubber. If inadmissibly high temperatures are detected, the actuator closes the damper to stop flue gas entering the scrubber. The other two actuators open dampers that divert the flue gas to an emergency stack. For maximum safety, these dampers are arranged in series in a 2002 (two out of two) configuration.

For several years now, functional safety and SIL have been a priority for AUMA as one of the world's leading manufacturers of electric actuators. The company offers an extensive product portfolio covering safety requirements up to SIL 3.

www.auma.com

High Performance Pump for Continuous Draft Tube Crystallizers (DTB)

EKATO Torusjet- impeller for increased efficiency and quality in the crystallization

The highest priority for continuously operated mass crystallizers is a constant and reproducible yield with high product quality. In the majority of cases this is associated with producing coarse-grained crystallized masses with a steady and narrow particle size distribution (PSD).

A typical apparatus for the continuous crystallization of a mass product is the DTB (Draft Tube Baffled) crystallizer, equipped with a draft tube and an axial pump impeller. Particularly important for a controlled particle size distribution and, hence, a consistent product quality, is the efficiency of this pump. This goes hand in hand with the reduction of local shear to avoid crystal attrition and hence uncontrolled nucleation with fine particles or even a bi-modular PSD.

The high-efficient **EKATO** TORUSJET-impeller has been developed by extensive experimental studies on impeller efficiency combined with CFD investigations of the flow patterns in the DTB. Its unique blade geometry combined with a corresponding set of guiding vanes and an optimum draft tube design avoids hydraulic loss by vortex formation. Drastically lower operational cost and optimum product quality are the result.

www.ekato.com

Sulzer's solutions for oil & gas at ADIPEC 2018

Visitors will experience key processing technologies thanks to augmented reality

The Abu Dhabi International Petroleum Exhibition and Conference (ADIPEC) 2018 is one of the world's leading events for the oil and gas sector, and this year it will be focusing on digital transformation of the industry. In line with this topic, **Sulzer** will present its latest developments in separation technology by means of innovative augmented reality (AR) apps. In addition, key solutions in pumping technology and rotating equipment services for the entire hydrocarbon value chain will be showcased.

Policymakers and industry experts in the oil and gas sector will gather together at the 21st edition of ADIPEC, taking place from November 12-15, to discuss and shape the future of upstream, midstream and downstream sectors in the Middle East and worldwide. Sulzer is committed to supporting Middle Eastern and worldwide businesses in the petroleum industry, showcasing its advances in mixing and separation technology, pump design and rotating equipment services on Stand 6150.

Sulzer Chemtech, market leader in mass transfer and static mixing, will present the latest developments in processing technology for gas/liquid and liquid/liquid separation for the oil and gas industry, including columns, column internals, mist eliminators and separator vessels.

Of particular interest will be the broad range of static mixers, particularly the SMX and SMX plus range for high-viscosity fluids. This equipment is designed to optimize the mixing processes and residence times while minimizing pressure drops. As a result, plant operators can benefit from highly efficient and reliable equipment that yields homogenous and consistent products.

Visitors will be able to learn about Sulzer Chemtech's process plant projects thanks to two AR apps. These will overlay images, videos, text and audio onto the physical world to provide a unique, hands-on experience of real-world chemical process plants, such as a downstream phenylenediamine isomer separation apparatus, and how Sulzer's equipment fits into them.

Attendees will also be able to discuss with Sulzer experts the solutions presented. In fact, besides developing state-of-the-art equipment, Sulzer is able to fully customize the solutions to your specific plant requirements. All these process solutions are developed and tested to ensure optimal performance.

In addition, Sulzer offers a number of services to ensure that customers can continuously benefit from the solutions provided. More precisely, installation supervisors and start-up engineers' support in building, installing and providing troubleshooting assistance for the equipment, while maintenance specialists provide guidelines and continuous support.

Visit Sulzer on Stand 6150 at ADIPEDC 2018. November 12-15, 2018 – Abu Dhabi National Exhibition Centre (ADNEC), Abu Dhabi, United Arab Emirates.

www.sulzer.com

Magnetic Drive Pumps: A Success All Made In Italy

CDR introduces model XTN and XTS: a cutting-edge solution designed for liquid with suspended solids.

In 2015, one of the most important **CDR** customer issued a challenge: to create a pump able to withstand the presence of solids, suitable for heavy duty processes, safe and reliable enough to avoid cloggings or failures typical of centrifugal pumps with double mechanical seals, and minimize production stops. In case of mechanical seal's failure, the customer occured the main issues: leakage of the barrier fluid contaminates the processed liquid and all the mixed solution has to be irremediably scrapped out, a very onerous task in terms of time and money.

Starting from these inputs, CDR developed an innovative magnetic driven pump, that is able to handle fluids with a certain content of suspended solids. The new technical solution was developed in a short time and tested directly on the working site. The mag driven pump achieved, in less than a year, outstanding results: no emission and no production stops, without any mechanical seal or external flushing: a real revolution!

With these new pumps, CDR has completely overcome the critical points above mentioned. The main operating principle of the XTN and XTS pump is to facilitate the free circulation of suspended solids. All internal passages between rotating and static parts have been designed in a way, that no solid particles can block the recirculating flow. As well, new completely open impellers and new bushes with generous canals contribute to obtain the final result: free circulation of suspsended solids and no clogging inside the pump.

Last but not least, bushes are executed in pure sintered silicon carbide with a diamond-like surface treatment, to reduce dramatically frictions between static and rotating bushes: this way the pump is protected in case of dry run.

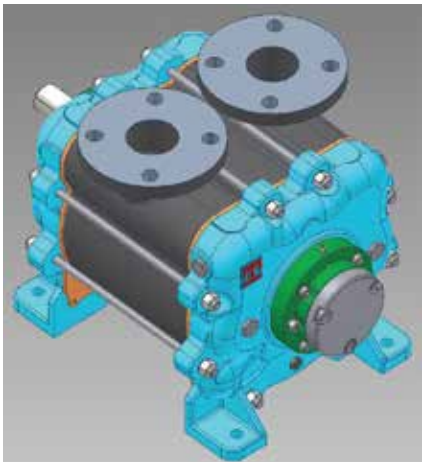
A real revolution for the magnetic driven pumps, now realized by CDR in two types: PFA version (XTN) and in SS316 version (XTS).

For more information, please visit

www.cdrpompe.com

TRVX 657 a new star is born

Pompetravaini, one of the world leaders in the design and manufacture of Liquid Ring Vacuum Pumps and Compressors, has launched the new TRVX 65 series. Following the TRVX 100 and TRVX 125 design philosophy, this new series offers a maximum flow of 535 m^3/h and vacuum down to 33 mbar absolute. Very compact design and low weight set this environmentally friendly pump at the top of its category. Featuring low noise and virtually no vibrations, thanks to the double bearing supports, TRVX 65 is suited for almost any industrial process. The nearly isothermal compression handles practically all gases and vapors. Available in different material configurations, the TRVX 65 series is designed with a small number of components and stainless-steel laser cut port plates for performance precision and higher cavitation protection. Inlet and outlet manifolds are embedded into the pump body: this increases the stiffness of the entire pump, and specifically at the flange connections, that meet both DIN EN and ANSI type. Sealing fluid flow is kept to the minimum: this enhances the pump efficiency and economy. Like the rest of the TRVX series, this pump is designed for easy regulation of mechanical fine settings, like the axial positioning of the impeller, without need for disassembling, even in the field. The TRVX 65 series can be used as compressor up to 2 barg discharge pressure. This is a pump built to last and maintain the lowest possible life cycle cost.



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a. Total Number of Copies (Net press run)	32,159	31,238
b. Legitimate Paid and/or Requested Distribution		
(1) Outside County Paid/Requested Mail Subscriptions	28,087	27,192
(2) Inside County Paid/Requested Mail Subscriptions	0	0
(3) Sales Through Dealers and Carriers, Street Vendors Counter Sales and Other Distribution Outside USPS	1,933	2,083
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(1) Outside County Nonrequested Copies	314	319
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e. Total Norequested Distribution	939	1,066
f. Total Distribution (Sum of 15c and 15e)	31,034	30,413
g. Copies not Distributed (Office, Returns, Spoilage, Unused)	1,125	825
h. Total (Sum of 15f and g)	32,159	31,238
i. Percent Paid and/or Requested Circulation	96.97%	96.49%

16. Electronic Copy Distribution: None Reported
17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the November 2018 issue of this publication
18. Signature of Fulfillment Manager: George Severine Date: 9/27/18

PS Form 3526-R, July 2014

Tailor-made valves

OHL Gutermuth makes specialist butterfly valves for the world's biggest projects

Valve manufacturer **OHL Gutermuth** offers a broad range of butterfly valves for both shut-off and control duties, plus special types, custom designs and accessories. Nominal diameters are up to DN 4000, with pressure ratings of 200 bar and more, for temperatures from –196°C to 1300°C. The firm has offered triple-offset butterfly valves for 20 years. The firm traces its origins back to 1867. "Providing individual advice and consulting to our customers right from the start is at the centre of our efforts," explains managing partner Wolfgang Röhrig. The Altenstadt-based company invests heavily in quality assurance, with certification to ISO 9001:2008 and Module H of the EU's Pressure Equipment Directive. All products are also certified under the Russian GOST and RTN standards and licensed for use by Gazprom. The company has operated a sales office in Beijing since 2007, and one in Moscow since 2011. "In the past 40 years we have supplied customized valves for more than 130 gas purification plants, among them the largest in the world, in Europe, Russia, Kazakhstan, Turkmenistan, India, China, the Middle East and America", says Röhrig. Recent projects include 220-ton valves for desulfurization plants in Iran, valves for the world's largest solar power stations and for the German and French navies.

You can visit OHL Gutermuth at Valve World, Hall 3, Booth E94.

www.ohl-gutermuth.de

Economic Indicators

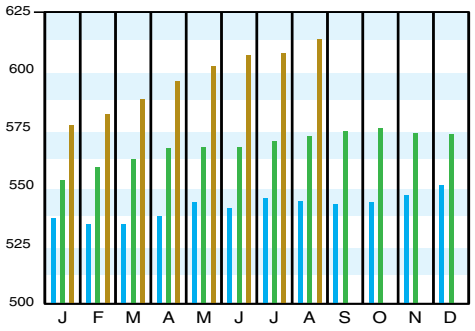
2016 2017 2018

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Aug. '18 Prelim.	July '18 Final	Aug. '17 Final
CE Index	613.6	607.2	571.9
Equipment	749.8	740.1	690.6
Heat exchangers & tanks	669.3	656.2	605.8
Process machinery	728.1	724.3	684.8
Pipe, valves & fittings	979.8	966.5	892.7
Process instruments	421.3	422.6	405.9
Pumps & compressors	1029.1	1025.8	984.7
Electrical equipment	539.7	538.0	521.7
Structural supports & misc.	826.6	809.9	741.4
Construction labor	335.7	335.7	330.0
Buildings	602.1	602.5	562.6
Engineering & supervision	307.5	307.6	310.5

Annual Index:
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5

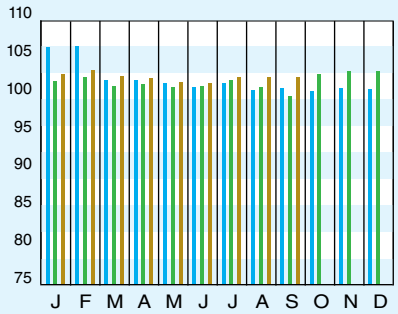


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

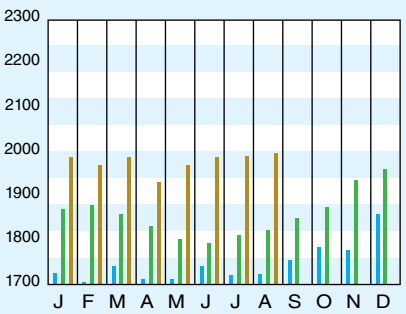
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Sept. '18 = 102.5	Aug. '18 = 102.7	Jul. '18 = 102.8	Sept. '17 = 98.7
CPI value of output, $ billions	Aug. '18 = 1,997.9	Jul. '18 = 1,991.3	Jun. '18 = 1,989.0	Aug. '17 = 1,781.6
CPI operating rate, %	Sept. '18 = 76.3	Aug. '18 = 76.4	Jul. '18 = 76.6	Sept. '17 = 74.1
Producer prices, industrial chemicals (1982 = 100)	Sept. '18 = 278.8	Aug. '18 = 279.1	Jul. '18 = 277.8	Sept. '17 = 254.2
Industrial Production in Manufacturing (2012 =100)*	Sept. '18 = 104.8	Aug. '18 = 104.6	Jul. '18 = 104.3	Sept. '17 = 101.3
Hourly earnings index, chemical & allied products (1992 = 100)	Sept. '18 = 185.7	Aug. '18 = 183.0	Jul. '18 = 183.7	Sept. '17 = 180.0
Productivity index, chemicals & allied products (1992 = 100)	Sept. '18 = 96.5	Aug. '18 = 97.7	Jul. '18 = 96.9	Sept. '17 = 94.0

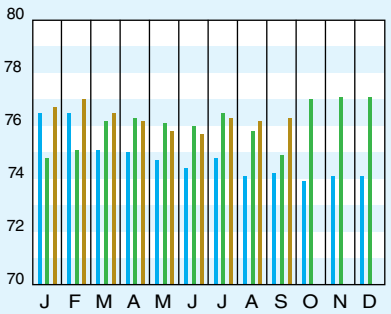
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the August 2018 *CE* Plant Cost Index (CEPCI; top; most recent available) increased compared to the previous month's value, continuing an upward trend that has been in place throughout 2018. The increase, however was driven by gains in the Equipment subindex and subcategories only. The Construction Labor subindex remained flat this month and the Buildings and Engineering & Supervision subindexes decreased slightly for August. The overall CEPCI for August stands at 7.3% higher than the corresponding value from August of last year. Meanwhile, the CBI data (middle) for Sept. 2018 show a small decrease in the CPI output index from August, and a small reduction in CPI operating rate.